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PRELIMINARY RESULTS OF BOTANICAL AND MICROBIOLOGICAL INVESTIGATIONS ON SEVERNAYA ZEMLYA 1995

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Abstract: This paper describes preliminary results from an expedition to Severnaya Zemlya in August 1995. As visits to individual sites were short and the informations gained cannot be regarded as complete, they provided only preliminary data about the botanical and microbiological inventory from nine different sites. The landscapes can be described as polar deserts with only sparse vegetation. Soils show permafrost at levels less than 50 cm. A diverse pattern of vegetation, bacterial counts and bacterial biomass was found at small scales with respect to relief, hydrology and bird's nesting places. The pattern of bacterial counts and biomass is mostly related to content of organic matter, especially to plant cover. Higher plants occur at most places and their abundance can be regarded as indicators of colonization processes where glaciers retreated recently.

1. Introduction

This expedition was part of a German-Russian research project dedicated to studies on the "Late Quaternary Environmental Development of Middle Siberia" and was due to prospect sites on Severnaya Zemlya for further expeditions. Together with the region of the Taymyr Peninsula, we find in this northern Siberian region all Arctic landscapes, *i.e.* boreal forests, tundras and cold deserts.

There is as yet no general evidence for Pleistocene glaciation, although the investigation of glacial processes in this region has been recognized as an important tool to understand the Quaternary history of the Taymyr-Severnaya Zemlya region and to reconstruct the Late Quaternary environmental history of the Laptev Sea system (SIEGERT and BOL'SHIYANOV, 1995).

The Severnaya Zemlya archipelago belongs to the northernmost region of the Eurasian continent. The landscape of this area is a typical area of polar deserts and belongs to the Siberian province of the Soviet polar deserts (ALEXANDROVA, 1988). Vegetation occurs only in small patches of several square meters and may flower best in the vicinity of bird colonies. The retreat of glaciers forms periglacial areas with barren soils where denuded soils occur. Such environments can be used for further studies on colonization processes, succession of microbial and plant communities as well as accumulations of organic matter and primary steps of soil formation.

2. Material and Methods

Figure 1 shows the area where the expedition took place, Table 1 shows the GPS positions and dates of the samplings. Climatology can be described in brief as follows: mean July temperature: +3°C, mean annual temperature: −13°C, 45–60 days per year with t>0°C, summer precipitation: 60 mm (ALEXANDROVA, 1988; BOL'SHIYANOV, pers. commun.). Soils show a pergelic temperature regime and aquic moisture regime on top. Periglacial soils show vesicular structure. Organic matter accumulation occurs in surface layers with different patterns of the state of degradation of organic matter (O/Ai/Ah-levels, PFEIFFER, pers. commun.), shows only low weathering state and is related to plant distributions.

The botanical description refers to plant surveys during visits to the individual locations as well as to inspections of samples collected and determinations in the laboratory. Those inspections, especially for lichens and mosses, are not completed for all samples at species level but give data at least at the genus level.

Microbiological sampling was carried out at 15 sites during the visits. Samples were placed in plastic containers and stored cool (0–5°C) until processing in the laboratory. Soil descriptions were carried out both in the field and in the laboratory for soil color, actual water content (%H_2O; 105°C, 24h) and loss of ignition (%LOI;

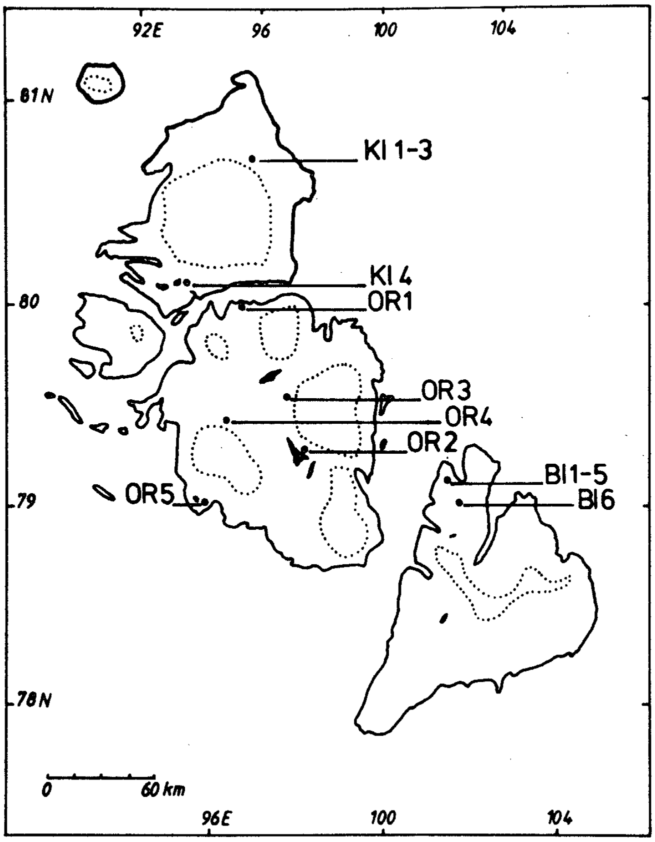

Fig. 1. Map of the Severnaya Zemlya Archipelago showing the sampling locations (cf. Table 1), dotted lines indicate glaciers.

Table 1. Severnaya Zemlya 1995, locations visited for soil sampling, botanical and microbiological studies. GPS-Data from Prof. Shuhei TAKAHASHI, Kitami Institute of Technology, Kitami, Japan.

Location area	Date	GPS-Position	Sample
Bol'shevik Isl., Prima Station	Aug. 8, 9	N79°15–16′, E101°37–49′	BI1-5
Bol'sh. Isl., Mushketova Glacier	Aug. 12	N79°10′02″, E102°09′34″	BI6
October Rev. Isl., North Coast	Aug. 10	N80°05′59″, E95°45′23″	OR1
October Rev. Isl., Fjord Lake	Aug. 10	N79°22′45″, E97°44′22″	OR2
Oct. Rev. Isl., Karpinskogo Glacier	Aug. 11	N77°36′30″, E97°11′18″	OR3
Oct. Rev. Isl., Vavilova Glacier	Aug. 11	N79°32′14″, E95°44′16″	OR4
Oct. Rev. Isl., Ismentchivoe Lake	Aug. 11	N79°06′10″, E91°12′04″	OR5
Komsomolsk Isl., Akad. N. Glacier	Aug. 10	N80°50′13″, E96°19′08″	KI1-3
Komsom. Isl., Geografik Lake	Aug. 10	N80°10′48″, E94°07′05″	KI4

450°C, 24h) as a rough estimate of the content of total organic matter.

The samples were analyzed for total counts of bacteria by epifluorescence microscopy using acridine orange as stain and blue light for excitation (BÖLTER *et al.*, 1993). Cells were counted and measured by image analysis equipment (LEITZ Aristoplan and Quantimed 500) at highest magnification (lens: PL Fluotar 100/1.32 oil, camera: SONY DXC-930P) which gave a resolution of 1 pixel=0.207 μm. Diameter of cocci and lengths of rods were calculated by using this relationship. Biovolume calculations follow the procedure given by BÖLTER *et al.* (1993).

3. Results and Discussion

3.1. Vegetation analysis

Table 2 gives an overview of the total plant species of vascular plants, mosses and lichens. Highest counts of total plant species were observed at sites BI1-5 (vicinity of Prima Station), OR2 (Fjord Lake) and KI4 (Geografik Lake); the latter two places were significantly influenced by birds: OR2 was in close distance of a colony of Kittiwake (*Rissa tridactyla*) and KI4 around an abandoned nest of an Brent Goose (*Branta bernicla*).

Table 3 presents the list of plants found on the main islands of Severnaya Zemlya. The most abundant vascular plants were *Cerastium* sp. (BI1-5, OR1, OR5

Table 2. Total counts of plant species at sites of Bol'shevik Island (BI1-5, BI6), October Revolution Island (OR1–OR5) and Komsomolsk Island (KI1-3, KI4).

Site	BI1-5	BI6	OR1	OR2	OR3	OR4	OR5	KI1-3	KI4
Vascularplants	12	0	2	7	4	3	3	1	4
Mosses	9	5	5	9	0	3	4	2	9
Lichens	16	12	1	9	5	0	3	0	8
Total	37	17	6	25	9	6	10	3	21

Table 3. List of plants from Severnaya Zemlya (August 1995). Dominant species are marked by an asterisk (*), species determined in samples in the laboratory are marked by a dollar sign ($).

1) Bol'shevik Island

1) Prima Station (N79°16'44", E101°37'24") August 8, 1995 and lake areas near Prima Station (N79°16'40", E101°40'34") August 12, 1995, (N79°15'13", E101°49'16") (sampling sites: BI1-5)

a) Vascular plants	b) Mosses	c) Lichens
Alopecurus alpinus (*)($)	*Andreaea* spp. (*)	*Alectoria* sp. ($)
Cerastium ?($)	*Aulacomnium turgidum* (*)($)	*Caloplaca* sp. ($)
Deschampsia sp. ($)	*Bryum cryophilum* (*)($)	*Cetraria cucullata* (*)
Draba sp. ($)	*Calliergon giganteum*	*C. nivalis* (*)
Novosieversia glacialis (*)	*C. obtusifolium* ($)	*Cladonia* spp. ($)
Papaver polare (*)	*C. sarmentosum* ($)	*Cornicularia* sp.
Poa abbreviata ($)	*C. giganteum* ($)	*Dactylina arctica* (*) ($)
P. arctica ($)	*Campylophus* sp.	*Dermatocarpon* sp. ?($)
Saxifraga cernua (*)($)	*Dichodontium* sp. ($)	*Ochrolechia frigida* (*)($)
S. caespitosa ($)	*Dicranoweisia crispula* (*)($)	*Sphaerophorus* sp.
S. nivalis ($)	*Dicranum* sp.	*Stereocaulon* sp. ($)
Stellaria?	*Ditrichum* sp. ($)	*Thamnolia vermicularis* (*)($)
(Minuartia?)	*Drepanocladus revolvens*	*Thamnolia* sp.
	D. exannulatus	*Umbilicaria* sp.
	Jungermannia sp. ($)	*Xanthoria elegans* (*)($)
	Orthothecium chryseum (*)($)	*X.* sp. ($)
	Philonotis sp.	
	Ptilidium ciliare (*)($)	
	Racomitrium lanuginosum (*)	
	Sanionia uncinata (*)	
	Schistidium apocarpum ($)	
	Scorpidium turgescens	

2) Mushketova Glacier, side moraine (N79°10'02", E102°09'34"), August 12, 1995 (sampling site: BI6)

a) Vascular plants	b) Mosses	b) Lichens
–	*Andreaea* sp.	*Alectoria* sp. (*)
	Bryum sp.	*Buellia* sp.
	Dicranoweisia sp.	*Cetraria* sp. (*)
	Dicranum sp.	*Lecanora* sp.
	Pogonatum sp.	*Lecidea* sp.
		Ochrolechia sp. (*)
		Parmelia sp. (*)
		Peltigera (Dermatocarpon?) sp.
		Rhizocarpon sp.
		Stereocaulon sp.
		Umbilicaria sp.
		Xanthoria sp.

Table 3 (Continued).

II) October Revolution Island

1) Flat plain at north coast (N80°05′59″, E95°45′23″), August 10, 1995 (sampling site: OR1).

a) Vascular plants	b) Mosses	c) Lichens
Cerastium sp.	*Aulacomnium turgidum* (*)	*Ochrolechia* sp.
Saxifraga caespitosa (*)	*Dicranum* sp.	
	Philonotis sp.	
	Sanionia uncinata	
	Tortura sp.	

2) Flat plain, near rookery (Rissa tridactyla) at Fjord Lake (N79°22′45″, E97°44′22″), August 10, 1995 (sampling site: OR2).

a) Vascular plants	b) Mosses	c) Lichens
Deschampsia brevifolia (*)	*Dicranum* sp.	*Cetraria* sp. (*)
Draba spp.	*Ditrichum flexicaule* (*)	*Cladia* sp. (*)
Papaver polare (*)	*Hylocomium splendens*	*Cornicularia* sp.
Phippsia sp.	var. *alaskanum* (*)($)	*Ochrolechia* sp. (*)($)
Saxifraga caespitosa (*)	*Orthothecium chryseum* ($)	*Parmelia* sp.
S. oppositifolia (*)	*Pogonatum* sp. (*)	*Ramalina* sp.
Salix polare (*)($)	*Polytrichum* sp. ($)	*Thamnolia vermicularis* (*)
	Sanionia uncinata	*Thamnolia* sp. ($)
	Schistidium apocarpum (*)($)	*Xanthoria elegans* (*)
	Tortura sp.	

3) Flat plain, east of Karpinskogo Glacier (N79°36′30″, E97°11′18″), August 11, 1995 (sampling site: OR3).

a) Vascular plants	b) Mosses	c) Lichens
Deschampsia sp. (*)	–	*Buellia* sp.
Eritrichium villosum		*Cetraria nivalis* (*)
Papaver polare (*)		*Lecidea* sp.
Saxifraga oppositifolia (*)		*Ramalina* sp.
		Thamnolia vermicularis

4) Flat plain, north of Vavilova Glacier (N79°32′14″, E95°44′16″), August 11, 1995 (sampling site: OR4).

a) Vascular plants	b) Mosses	c) Lichens
Draba sp. (*)	*Bryum* sp. c. fr.	–
Papaver polare (*)	*Dicranum* sp. c. fr.	
Saxifraga oppositifolia (*)	*Ditrichum* sp. c. fr.	

5) Flat plain along coast of Izmentchivoe Lake (N79°06′10″, E91°12′04″), August 11, 1995 (sampling site: OR5).

a) Vascular plants	b) Mosses	c) Lichens
Cerastium sp.	*Ditrichum* sp.	*Cetraria nivalis* ?
Papaver polare (*)	*Loeskypnum badium*	*Lecidea* sp.
Saxifraga oppositifolia (*)	*Orthothecium chryseum* (*)	*Thamnolia vermicularis* (*)
	Sanionia uncinata (*)	

Table 3 (Continued).

III) Komsomolsk Island		
1) North edge of Akademik Nauk Glacier (N80°50′13″, E96°19′08″), August 10, 1995 (sampling site: KI1-3)		
a) Vascular plants	b) Mosses	c) Lichens
Cerastium biatynickii (*)($)	*Bryum sp.* (*)($) *Pogonatum* sp. (*)($)	–
2) Coast of Geografik Lake, south of Akademik Nauk Glacier (N80°10′48″, E94°07′05″), August 10, 1995 (sampling site KI4)		
a) Vascular plants	b) Mosses	c) Lichens
Cerastium regelii? ($) *Papaver polare* (*) *Saxifraga caespitosa* (*) *S. oppositifolia* (*)	*Bryum cryophilum* (*)($) *Ditrichum flexicaule* (*)($) *Drepanocladus revolvens* ($) *Orthothecium chryseum* (*)($) *Philonotis* sp. ($) *Pogonatum* sp. ($) *Sanionia uncinata* (*)($) *Tomenthypnum nitens* (*)($) *Tortula* sp. ($)	*Candelariella* sp. (*)($) *Cetraria nivalis* *Cetraria* spp. ($) *Cornicularia* sp. ($) *Hypogymnia* sp. ($)) *Parmelia* sp. ($) *Ochrolechia* sp. (*)($) *Thamnolia vermicularis* (*)($)

KI1-3, KI4), *Papaver polare* (BI1-5, OR2, OR3, OR4, OR5, KI4), *Saxifraga caespitosa* (BI1-5, OR1, OR2, KI4) and *S. oppositifolia* (OR2, OR3, OR4, OR5, KI4). Mosses showed a wider taxonomic range; 7 species were most abundant (*Detrichum flexicaule* (OR2, OR4, OR5, KI4), *Dicranum* sp. (BI6, OR1, OR2, OR4), *Pogonatum* sp. (BI6, OR2, KI1-3, KI4), *Sanionia* sp. (OR1, OR2, OR5, KI4), *Bryum* sp. (BI6, OR4, KI1-3), *Orthothecium chryseum* (OR2, OR5, KI4), *Tortura* sp. (OR1, OR2, KI4). Most abundant lichens were *Cetraria nivalis* (BI1-5, OR3, OR5, KI4), and *Thamnolia vermicularis* (BI1-5, OR2, OR3, OR5, KI4), further *Cetraria* sp. (BI6, OR2, KI4), *Cornicularia* sp. (BI1-5, OR2, KI4), *Lecidea* sp. (BI6, OR3, OR5), *Ochrolechia* sp. (BI6, OR2, KI4), and *Parmelia* sp. (BI6, OR2, KI4).

The role of flowering plants in polar deserts is of only minor importance. Cryptogams, *i.e.* mosses and lichens, form the dominant plant aggregations. As the Severnya Zemlya archipelago belongs to the Siberian province, floral components have a more continental character in comparison to other Arctic islands. Mostly species with a circumpolar distribution can be found here which belong to the Siberian and Siberian-American species, *e.g. Eritrichum villosum, Novosieversia glacialis* (ALEXANDROVA, 1988).

The northern island, Komsomolsk Island, is part of the northern belt of the Siberian province, it showed the most impoverished vegetation. Only six species of vascular plants were found here; all of them have been mentioned in earlier reports of KOROTKEVICH (1958), KHODACHEK (1980) and SAFRANOVA (1981).

The two other islands described here, October Revolution Island and Bol'shevik Island, belong to the southern belt of the Siberian province. More detailed data of their vegetation are presented by KOROTKEVICH (1958), SAFRANOVA (1976, 1981) and KHODACHEK (1980); they are summarized for vascular plants by ALEXANDROVA (1988).

Most of the genera mentioned above were also found at locations of Alexandra Fiord, Ellesmere Island, when comparing the plant list from MAAS and NAMS (1994) for lichens, MAAS *et al.* (1994) for bryophytes, and BALL and HILL (1994) for vascular plants. This comparison, however, needs several verifications and can only be preliminary at this stage.

Lichens play the major role in plant cover on polygons, mainly *Cetraria* sp., *Alectoria* sp. and crustose forms. Vascular plants are distributed either in the form of individual patches in wet and plain areas or as strips between polygons. They are often associated with mosses. Species of *Deschampsia, Saxifraga, Novosieversia* and *Papaver* dominate our observations. Shrubs (*Salix polare*) were found only on October Revolution Island*). This species, however, belongs to an extrazonal vegetation in sheltered areas (KOROTKEVICH, 1958; ALEXANDROVA, 1988). Data of the vegetation patterns of mosses and lichens are only little known. These plants follow the patterns of polar deserts; species of tundra biotopes are found only seldom in associations of extrazonal types of vegetation (ALEXANDROVA, 1988; ZHURBENKO, pers. commun.).

3.2. Soils and microbiological study

Table 4 presents the sampling depths, soil colors, actual water contents and the values obtained by loss on ignition (LOI). The content of organic matter as measured by LOI is generally in the range of 3 to 8%, *i.e.* between 1 and 3% carbon. Samples taken from plants, *e.g.* BI4.1 (sample from peaty material of a cushion of *Novosieversia glacialis*) and samples BI3.1, BI5.1, OR2.1, OR5.1 and KI4.1 show higher contents due to the plant material. Many samples, even those from apparently denuded areas, were found to be colonized by algae, mainly cyanophytes and some diatoms, which in turn contributed to the total organic matter (LOI).

Generally, the picture obtained from the organic material is reflected by the bacterial counts (TBN, Fig. 2). Sample BI4.1 shows the highest count. The other cushions do not show such high counts; they show values below 10^9 cells per gram of dry soil. Deep layers from sites BI3 and BI5 as well as samples from sites BI6 (moraine of Mushketova Glacier) and KI1-3 (foreland of Akademik Nauk Glacier) show the lowest counts as they are samples from frost heaves or from typical cold desert plains. This, however, is not reflected by direct correlations between TBN and LOI, due to the small numbers of samples, but indicates an apparent trend (Fig. 3).

The mean bacterial cell volume of studied samples as calculated from geometrical factors (BÖLTER *et al.*, 1993) shows values between 0.041 and 0.074 μm^3, where only the highest values (>0.07 μm^3) can be attributed to high amounts of organic matter (*e.g.* samples BI4.1, BI5.1).

Antarctic soils, as measured by comparable microscopic methods, have shown values between 0.06 and 0.14 μm^3 (BÖLTER, 1992), 0.03 and 0.43 μm^3 (BÖLTER, 1993)

*During a visit in July 1996, *Salix polare* was found also at Bol'shevik Island (BÖLTER, PFEIFFER, ZHURBENKO, in preparation).

Table 4. Soil properties on Severnaya Zemlya.

Sample	Depth (cm)	Remark	Munsell-colour[1]	% H_2O	% LOI
BI1.1	0–2	sand	2.5Y4/3	25.11	5.36
BI2.1	0–2	sand	2.5Y5/3	12.15	5.79
BI2.2	2–4	sand	2.5Y4/3	14.38	4.93
BI3.1	0–1	cushion	7.5YR2/0	54.29	30.26
BI3.2	1–3	sand	2.5Y4/4	30.02	7.86
BI4.1	2–5	cushion	10YR2/2	55.48	91.17
BI5.1	0–1	cushion	7.5YR2/0	37.95	50.07
BI5.2	1–3	sand	5Y3/1	12.16	8.64
BI6.1	0–2	sand	5Y4/2	9.63	6.66
BI6.2	2–4	sand	5Y4/2	9.29	7.25
OR1.1	0–2	sand	7.5YR4/4	17.74	6.94
OR2.1	0–2	cushion	7.5YR3/3	47.98	24.66
OR2.2	2–4	sand	7.5YR3/4	25.62	8.18
OR3.1	0–1	sand	7.5YR4/3	14.87	6.44
OR3.2	1–3	sand	7.5YR4/2	12.88	6.02
OR4.1	0–1	cushion	5YR3/4	22.49	7.40
OR4.2	1–4	sand	5YR3/4	13.79	6.32
OR5.1	0–2	sand	5YR3/3	46.89	13.13
OR5.2	0–5	sand	5YR3/2	3.45	5.59
KI1.1	0–1	sand	2.5Y5/3	9.21	3.86
KI1.2	2–5	sand	2.5Y5/4	6.76	3.50
KI1.3	5–10	sand	2.5Y5/4	8.76	3.35
KI2.1	0–2	sand	2.5Y4/3	18.90	3.31
KI3.1	0–2	sand	2.5Y5/2	14.73	4.87
KI4.1	0–2	sand	2.5Y2/0	38.44	14.44
KI4.2	2–5	sand	7.5YR3/4	20.98	6.98

[1]According to MUNSELL SOIL COLOUR CHARTS (1994).

for soils and plant cushions from continental Antarctica and between 0.05 and 0.61 μm^3 for soils from the maritime Antarctic (BÖLTER, 1995). The variability found at Severnaya Zemlya is much lower.

Despite this, the individual samples show strong heterogeneity regarding the bacterial size distributions. The maximal length of bacteria in the samples was about 2.25 μm. The majority of bacteria can be found in the size classes of cocci (0.25–0.5 μm in diameter; mean: 33.7% of the total community, range: 22.4–43.9%) and rods (0.5–1.0 μm in length; mean: 39.0%, range: 22.8–49.3%). These data show that small bacteria dominate the community. Whether this is due to low amounts of actually available material or to other environmental constraints cannot be determined now, but needs further analysis of the pool of organic matter and the activity of the bacterial community in total. Further, significant shifts in the size class distributions of the individual communities can be found.

This first combined study of plant cover and the microbiological inventory of the surface soils from Severnaya Zemlya has shown us interesting features of soil biology of those northernmost environments. The study will be completed by data from soil

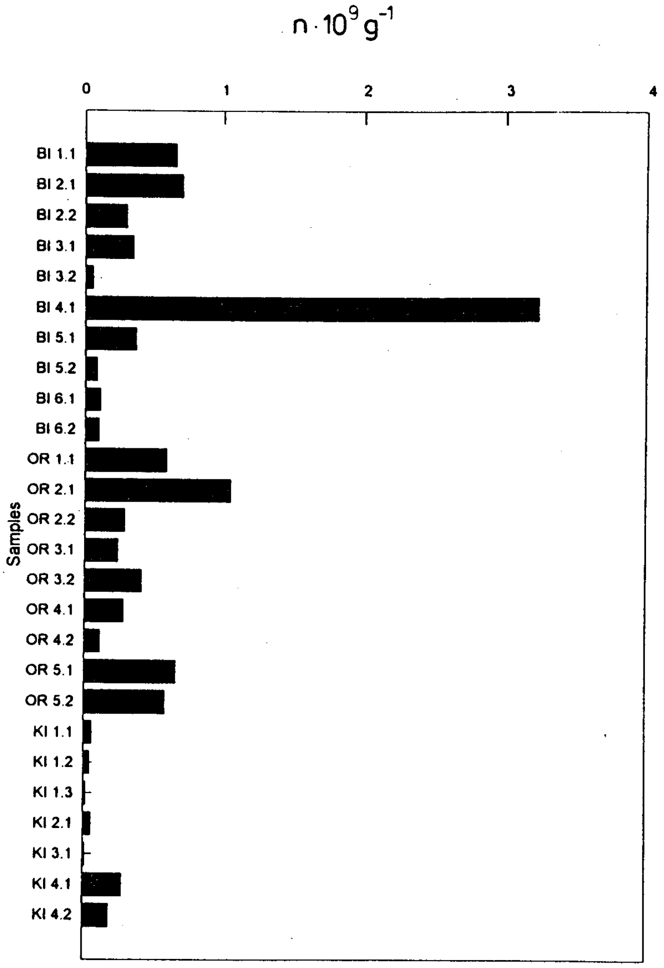

Fig. 2. *Total counts of bacteria ($n \cdot 10^9 g^{-1}$ d wt soil or plant material, respectively).*

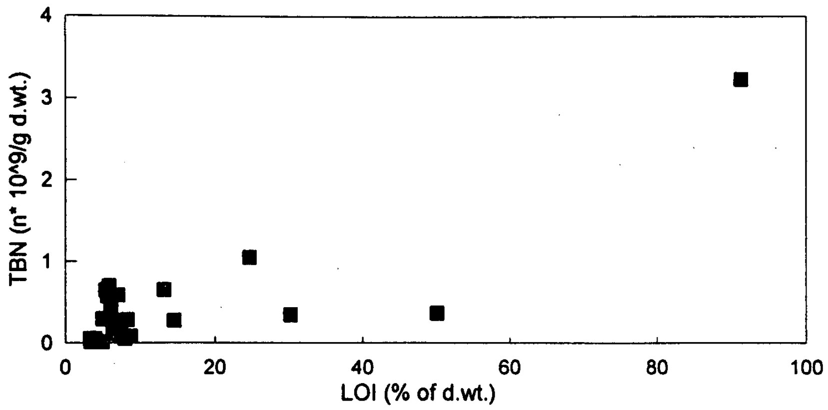

Fig. 3. *Relationship between bacterial counts and loss on ignition (LOI).*

science in the near future (PFEIFFER, in prep.) with special respect to soil taxonomy and the analysis of soil organic matter. Thus we will find a better picture for the understanding of colonization processes and further succession in the biological steps.

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