Chinese Journal of Polar Science, Vol. 19, No. 1, 63 – 76, June 2008

Plant Community and Nutrient Status of the Soils of Schirmacher Oasis, East Antarctica

Shiv Mohan Singh[1], Jagdev Sharma[2], Rasik Ravindra[1] and Purnima Singh[3]

1 National Centre for Antarctic and Ocean research, Goa 403804, India

2 National Research Centre for grapes, Pune-412307, India

3 Purvanchal University Jaunpur, India

Received June 17, 2008

Abstract Investigations on plant community and micronutrient status of Schirmacher Oasis, East Antarctica have been presented in this paper. The dominant plant communities include moss and lichen. The frequency of species occurrence and changes in species composition at different location varied. Thirty-four soil samples were analyzed for chemical properties of the soils of Schirmacher Oasis and Nunatak, East Antarctica. The most common plant species growing throughout the areas of Schirmacher Oasis and Nunataks are: *Candelariella flava* (lichen) and *Bryum pseudotriquetrum* (moss). Large variations were observed among different soil samples in all the nutrients and other measured soil chemical parameters. The soils are characterized by acidic pH ranging from 4.42 – 6.80. The mean organic carbon content was 0.62 and ranged from 0.06 – 1.29%. The electrical conductivity in 1 : 2 soil water ratio ranged from 0.06 – 1.29. The average content of macronutrient cation, which are ammonium acetate extractable was in the order of Ca > K > Na > Mg. The average content of DTPA extractable micronutrient cations was in the order of Fe > Mn > Cu > Zn. Thirty one out of 34 samples contained less than 0.80 ppm DTPA extractable Zn. Correlation studies revealed that content of macronutrient cations significantly and positively correlated to that of chlorides. Electrical conductivity exhibited significant and positive relationship with pH, K, Ca, Mg, Na and chloride content. Sodium ($r = 0.876^{**}$) exhibited highest correlation followed by K ($r = 0.831^{**}$) with chloride content. The correlation coefficient for chlorides was higher with electrical conductivity ($r = 0.732^{**}$) than pH ($r = 0.513^{**}$). Organic carbon content of the soil was positively correlated with Fe ($r = 0.442^{*}$). The nutrient status did not appear to be a limiting factor in growth of plants. Lichen and moss community structure and composition in the study area were not related with fertility status of soil. Terrestrial mosses are most abundant and luxuriant along the soil habitats near bank of water bodies and the melt water streams.

Key words Antarctica, Schirmacher Oasis, Nutrient, Lichen, Moss.

1 Introduction

Scientific expeditions by Indians at Schirmacher Oasis of East Antarctic region have been a regular feature since 1981. Due to harsh climatic conditions, most of the soil formation results from weathering processes or microbial activities on sparse organic material, produced under stone shelters or depressions. Due to increases in summer temperatures in the Antarctica and glacial retreat in particular, fresh area is exposed. This promotes the processes of soil formation. Further this offers an opportunity to study the physico-chemical and biological properties of soil including nutrient availability, which are important for supporting the flora and fauna. Soil properties influence soil forming processes. Accumulation of soil organic matter and podzolization are important up to the Antarctic polar desert[1].

Soil properties like soil reaction and salinity influence the conditions for micro biotic processes and adaptation of plant and microbial communities. Hazra[2] found highly significant correlation between pH and soil nematode population. In soils of Mawson Base and the Vestfold Hills, east Antarctica; relationships were evident between the components of the microflora and electrical conductivity of soil[3]. There was a strong correlation between plant Ca and pH of the substrate in Signy Island, South Orkney Islands[4]. The information on plant communities in the study area of Schirmacher Oasis and Nunatak, East Antarctica as also the information on availability of nutrients, which support the survival of these plant communities is lacking. The present study was undertaken to study the relationship between nutrient regimes of soils and plant communities in area of investigation.

2 Materials and Methods

Topographically, the area can be divided into three distinct units, the southern continental ice-sheet, central landmass exposed as structural hills and valleys and the northern ice shelf. The central landmass spread over about 57sq km is known as Schirmacher Oasis (70°44′ - 70°46′S; 11°20′ - 11°55′E). It has a maximum width of 3.5 km and a length of about 17 km and is aligned in a general East-West trend. It's elevation varies between 0 and 236 m above the mean sea level. The area has three types of lakes viz. Pro-glacial lake, Land locked lakes and Epi-shelf lakes[5]. The average annual temperature is - 10℃ and means wind velocity of about 10 ms^{-1}. The average precipitation (snow) ranges between 250 - 300 mm and relative air humidity is 15 - 20%. During polar summer ice melts and water flows often into the lakes. The valleys are ice-free because the Mountains block the flow of ice from the polar plateau and low precipitation and strong Katabatic winds lead to little accumulation of snow in the area. The lakes occupy closed basins and vary in surface area, depth, and ice-cover thickness. Thirty four GPS locations (Table 1) of Schirmacher Oasis and nearby Nunataks of Dronning Moud Land, East Antarctica were sampled in the present study (Fig. 1). Soil samples were also collected from Nunataks. Lichens, mosses, microbial mats growths were visible to the naked eye as blackish, greenish-brown or as green growths at moist habitat.

The present materials were collected from oasis and adjoining Nunataks during January-February 2004. Soil samples were collected near streams, ponds, lakes and areas of moss carpet. Lichen and mosses were air-dried and safely packed in sterile bag for species determination at laboratory. The lichens and mosses were observed with a Nikon & Olympus microscopes equipped with image analysis software. All samples are stored in Polar Biology repository at NCAOR, Goa.

Soil samples from same GPS locations were also collected and analysed for soil chemical parameters. The undecomposed organic residues were removed. The soil samples were air dried and crushed gently in a wooden pestle and mortar passed through 2 mm sieve for chemical analysis. Soil pH and EC were determined in water using 1: 2.5 (soil: water ratio) and 1: 2 (soil: water ratio), respectively. Organic carbon by wet digestion method[6], available/mineralizable N by steam distillation method[7] using Gerhardt make VAP 30 apparatus, available P was estimated by following Bray and Kurtz[8] colour development method on a UV-VIS spectrophotometer. Calcium, Mg, Na and K were extracted using neutral normal ammonium acetate. Available Zn, Cu, Fe and Mn were extracted by DTPA method[9] and determined by atomic absorption spectrophotometer (Perkin Elmer Analyst 100 model). The chlorides in water extract were determined by titration method using silver nitrate.

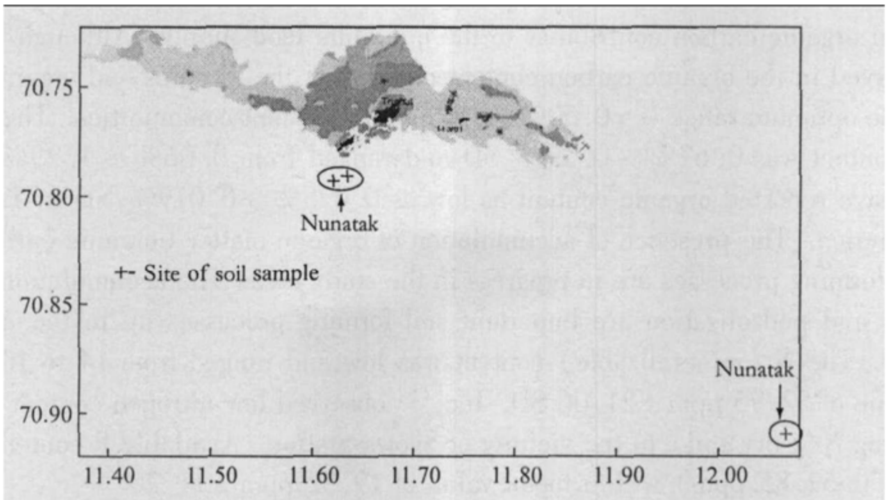

Fig. 1 Location map of the soil sample in Scirmacher Oasis and adjoining Nunatak. (Based on Ravindra *et al.* 2001[5])

3 Results and discussions

Plant communities:

The terrestrial plant communities at different GPS locations on soil habitat were recorded. These include species of lichens and mosses. The frequency of species occurrence and changes in species composition at different location varied. The lichen species growing on soil-moraine and moss habitats of Schirmacher Oasis are: *Acarospora williamsii* Filson, *Buellia grimmiae* Filson, *Caloplaca citrina* (Hoffm.) Th. Fr., *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis, *Lepraria cacuminum* (A. Massal.) Lohtander, *Lecanora expectans* Darb., *Lecanora geophila* (Th. Fr.) Poelt, *Lecidella siplei* (CW Dodge & GE Baker) May. Inoue, *Lecidella* sp. B, *Physcia caesia* (Hoffm.) Furnr. *Rinodina olivaceobrunea* CW Dodge & GE Baker. Terrestrial mosses were most abundant and luxuriant along the soils habitats near bank of water bodies and the melt water streams. The moss community of Schirmacher Oasis includes species of *Bryum argenteum* Hedw. *var. muticum* Brid., *Bryum archangelicum* Bruch & Schimp, *Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb, *Ceratodon purpureus* (Hedw.) Brid, *Orthogrimmia sessitana* (De Not.) Ochyra & Zarnowiec, Syntrichia *sarconeurum* Ochyra & RH Zander.

These species were abundant on soil surface near the edge of the streams. The most common plant species growing throughout the areas of Schirmacher Oasis and Nunataks are: *Candelariella flava* (lichen) and *Bryum pseudotriquetrum* (moss).

Soil parameters:

The diversity in the fertility status of the soils with respect to micronutrients is presented in Table1. The soils are characterized by an acidic pH ranging from 4.42 to 6.80. The earlier studies of cryosoils from eastern Antarctica also characterized the soils acidic in reaction[2]. The electrical conductivity ranged from 0.06 to 1.22 dS/m with a mean value of 0.34 dS/m ±0.27 SD.

Total organic carbon contributes to the microbial food supply. Although large variation was observed in the organic carbon content majority of the samples had organic carbon content in the optimum range (>0.50%) to support the plant communities. The mean organic carbon content was 0.62% −0.29% SD and ranged from 0.06% −1.29%. Burikins *et al.* [10] have reported organic content as low as 0.025% ±0.019% SD in Taylor valley of the Antarctica. The presence of accumulation of organic matter (organic carbon) indicated that soil-forming processes are in progress in the study area. The accumulation of soil organic matter and podzolization are important soil-forming processes up to the Antarctic polar desert[1]. The N (mineralizable) content was low and ranged from 14 to 105 ppm with a mean value of 52.95 ppm ±21.06 SD. Ino[11] observed low nitrogen content (range 0.011 to 4.51 mg N/g dry soil) in the vicinity of Syowa Station. Available P content varied widely (5.46 to 52.85 ppm) with a mean value of 19.32 ppm ±11.20.

Among the neutral normal ammonium acetate extractable cations calcium was the most abundant followed by potassium and sodium. Potassium ranged from 50 − 355 ppm, Ca from 50.05 to 357 ppm, Mg from 16 to 152.5 ppm and sodium from 25 to 297.25 ppm. The mean values for K, Ca, Mg and K were 116.01, 170.17, 68.38 and 102.42 ppm, respectively. The chloride content in water extract varied greatly (8.87 to 275 ppm) with a mean value of 74.77 ppm ±56.30.

The DTPA extractable Fe content was the highest among all the four-micronutrient cations studied followed by manganese in all the soil. The iron content ranged from 14.3 to 101 ppm with a mean value of 51.16 ppm ±25.56. The manganese content was very low compared to iron and ranged from 0.79 to 6.36 ppm with a mean value of 2.43 ppm ± 1.16. The mean Cu content of the soil was 0.89 ppm ±0.61 indicating a wide variation. The zinc content also varied widely in different soils from 0.22 to 1.33 ppm with a mean value of 0.5 ppm ±0.23. On an average the soil contained higher Cu than Zn. The soils contained abundant amounts of micronutrients for the growth of the vegetation. Considering the critical limits of DTPA extractable micronutrient cations from higher plant growth point of view (0.20 ppm for Cu, 0.80 ppm for Zn, 4.50 ppm for Fe, and 1.0 ppm for Mn), all the soil samples were high in Cu and Fe and only two samples were deficient in Mn. However, all the soil samples except three were deficient Zn. The data presented above showed a large variation in all the micronutrient contents. Bayer and Bolter[1] observed a high variability in soil geography and soil properties at both a profile and landscape level.

Table 1. Plant community and some chemical characteristics of the Schirmacher Oasis, East Antarctic soils

Latitude/ Longitude	Elevation (meters)	pH (1:2.5)	EC (1:2) (dS/m)	OC (%)	Mineralizable N	Available -P	Neutral N NH_4OAc extractable cations (ppm)				Water soluble Cl^- (ppm)	DTPA extractable micronutrient cations (ppm)				Plant community	
							K	Ca	Mg	Na		Cu	Zn	Fe	Mn	Lichen	Moss
70°44′38.2″S 11°28′41.7″E	188	4.86	0.06	0.21	28	10.67	52	70.3	33.4	44.5	107	0.42	0.25	14.3	3.68	*Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis, *Lecidella* sp. *B*,	Absent
70°44′47.1″S 11°28′47.4″E	120	6.25	0.75	0.57	14	5.46	155	325.5	112.5	220	160	0.4	0.41	56.8	1.4	Absent	*Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb
70°44′52.8″S 11°40′14.8″E	101	5.1	0.13	0.57	49	23.43	80	91	52	55	35.5	0.36	0.3	32.8	1.47	*Physcia caesia* (Hoffm.) Furnr., *Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis, *Lecidella siplei* (C. W. Dodge & G. E. Baker) May. Inoue. *Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Lepraria cacuminum* (A. Massal.) Lohtander *Acarospora williamsii* Filson, *Lecanora geophila* (Th. Fr.) Poelt	Absent
70°44′54.7″S 11°40′32.3″E	140	5.52	0.36	0.6	35	27	112.2	141	98.4	108.3	88.8	0.8	0.68	29.9	1.58	*Acarospora williamsii* Filson, *Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis, *Physcia caesia* (Hoffm.) Furnr., *Lecanora expectans* Darb., *Lepraria cacuminum* (A. Massal.) Lohtander	Absent
70°45′04.3″S 11°40′19.7″E	142	4.85	0.07	0.12	14	12.23	50	108	16	25	8.87	0.42	0.56	64.6	1.32		*Bryum* species

70°45′07.5″S 11°40′16.7″E	156	6.65	1.22	0.48	63	18.8	355	357	100.5	297.3	275	1.63	0.73	25.7	3.9	*Caloplaca citrina* (Hoffm.) Th. Fr., *Lecanora expectans* Darb., *Acarospora williamsii* Filson	Absent
70°45′10.7″S 11°32′26.3″E	147	4.87	0.23	0.42	63	47.9	87.5	135	56	55	44.4	2.12	0.42	40.5	1.67	*Acarospora williamsii* Filson, *Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis, *Lecanora geophila* (Th. Fr.) Poelt	*Bryum* species
70°45′12.6″S 11°44′18.8″E	39	6.8	0.37	0.33	35	18.22	180	189.5	75.5	100	44.4	2.6	0.64	60.2	2.87	Absent	*Syntrichia sarconeurum* Ochyra & R. H. Zander, *Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb, *Bryum argenteum* Hedw. var. *muticum* Brid., *Ceratodon purpureus* (Hedw.) Brid,, *Orthogrimmia sessitana* (De Not.) Ochyra & Zarnowiec
70°45′25.1″S 11°44′04.1″E	64	5.51	0.12	0.68	56	15.88	95	204	63.5	95	44.4	0.6	0.44	91.5	1.73	Absent	*Bryum* species
70°45′22.3″S 11°44′16.6″E	59	5	0.1	0.96	84	13.8	140	256	86.5	75	124	1.87	0.55	101	2.72	*Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis, *Lecanora expectans* Darb., *Caloplaca citrina* (Hoffm.) Th. Fr., *Lepraria cacuminum* (A. Massal.) Lohtander	*Bryum* sp,

70°45′35.4″S 11°45′38.6″E	133	5.83	0.23	0.72	49	10.67	92.5	210	78.5	90	79.9	0.57	0.33	31.5	3.18	*Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis, *Lecanora expectans* Darb. *Lecanora geophila* (Th. Fr.) Poelt.	Absent
70°45′36.4″S 11°44′02.6″E	100	4.97	0.87	0.9	70	8.85	72.5	106	33	65	26.6	0.63	0.52	41.4	1.42	*Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Lepraria cacuminum* (A. Massal.) Lohtander, *Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis *Lecanora expectans* Darb., *Caloplaca citrina* (Hoffm.) Th. Fr. *Lecidella siplei* (C. W. Dodge & G. E. Baker) May. Inoue	Absent
70°45′39.2″S 11°49′02.0″E	99	5.85	0.23	1.08	105	13.28	150	50.05	103.5	120	44.4	1.49	0.51	51	3.78	*Caloplaca citrina* (Hoffm.) Th. Fr., *Lecanora expectans* Darb., *Lepraria cacuminum* (A. Massal.) Lohtander	Absent
70°45′41.2″S 11°41′38.5″E	146	4.8	0.12	0.57	56	9.37	82.5	166.5	60.5	70	35.5	0.79	0.4	72	1.46	Absent	*Bryum archangelicum* Bruch & Schimp, *Ceratodon purpureus* (Hedw.) Brid,
70°45′42.1″S 11°44′03.2″E	106	5.57	0.23	0.66	63	31.24	85	174.5	65.5	80	26.6	0.94	0.56	95	6.36	*Caloplaca citrina* (Hoffm.) Th. Fr., *Candelariella flava* (C. W. Dodge & Baker) Castell & Nimis, *Lecanora expectans* Darb., *Lepraria cacuminum* (A. Massal.) Lohtander	Absent

70°45′43.6″S 11°43′45.7″E	118	5.08	0.16	0.45	70	15.1	75	125	50	65	53.3	0.58	0.93	89.2	3.11	*Candelariella flava* (C. W. Dodge & Baker) Castello Nimis, *Caloplaca citrina* (Hoffm.) Th. Fr., *Lecanora expectans* Darb., *Lecanora geophila* (Th. Fr.) Poelt.	*Ceratodon purpureus* (Hedw.) Brid.
70°45′44.4″S 11°45′58.5″E	122	5.3	0.12	0.06	42	52.85	55	103	53	50	44.4	0.54	0.32	22.8	2.01	*Lecanora expectans* Darb., *Caloplaca citrina* (Hoffm.) Th. Fr.,	*Bryum* sp.
70°45′47.0″S 11°41′28.9″E	148	4.78	0.38	0.51	28	11.97	95	102.5	53.5	115	97.6	0.33	0.36	32.9	1.2	*Acarospora williamsii* Filson, *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis, *Lecidella siplei* (C. W. Dodge & G. E. Baker) May. Inoue, *Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Lepraria cacuminum* (A. Massal.) Lohtander	Absent
70°45′49.2″S 11°40′46.7″E	149	4.86	0.06	0.35	42	13.53	50	65.4	19	40	17.8	0.26	0.23	24.3	1	Absent	*Orthogrimmia sessitana* (De Not.) Ochyra & Zarnowiec.
70°45′49.8″S 11°45′55.2″E	92	5.27	0.22	0.57	77	15.62	95	139.5	78.5	75	26.6	0.63	0.69	27.7	2.64	*Caloplaca citrina* (Hoffm.) Th. Fr.	*Ceratodon purpureus* (Hedw.) Brid,, *Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb,

70°45′50.8″S 11°41′46.0″E	140	5.39	0.11	0.24	49	6.76	70	51	34	70	44.4	0.29	0.29	22.8	1.51	*Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis, *Lecanora geophila* (Th. Fr.) Poelt	Absent
70°45′51.0″S 11°42′46.0″E	233	4.58	0.39	1.08	63	16.92	80	223	59	65	35.5	0.52	0.49	98	1.15	*Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Candelariella flava* (C. W. Dodge & Baker) Castell° & Nimis, *Lepraria cacuminum* (A. Massal.) *Lohtander*, *Caloplaca citrina* (Hoffm.) Th. Fr., *Lecanora expectans* Darb.	Absent
70°45′51.6″S 11°36′45.0″E	144	5	0.15	1.02	63	26.5	92.5	106	41.5	90	44.4	0.34	0.56	66.7	1.9	*Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Lepraria cacuminum* (A. Massal.) Lohtander *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis *Acarospora williamsii* Filson, *Lecanora geophila* (Th. Fr.) Poelt	Absent
70°45′53.5″S 11°46′14.1″E	20	5	0.15	0.69	21	12.5	70	109	43.5	50	35.5	0.48	0.37	29.1	2.39	*Acarospora williamsii* Filson	Absent
70°45′54.3″S 11°44′42.9″E	130	6.46	0.44	0.42	22.13	10.93	90	333	152.5	100	62.1	2.04	0.22	16.7	2.4	Absent	*Bryum* species.
70°45′54.8″S 11°44′42.9″E	130	6.35	0.88	0.51	63	10.41	225	238	96	210	213	0.91	0.62	65.9	4.12	*Acarospora williamsii* Filson, *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis, *Caloplaca citrina* (Hoffm.) Th. Fr.,, *Lecanora expectans* Darb	*Ceratodon purpureus* (Hedw.) Brid, *Bryum pseudotriquetrum* (Hedw.) P. Gaertn., B. Mey. & Scherb

70°46′07.5″S 11°48′00.8″E	133	5.71	0.4	0.63	42	13.5	150	283	94.5	120	96	0.87	0.52	53.1	2.78	*Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis	Absent
70°46′08.6″S 11°45′08.6″E	140	5.25	0.37	0.57	63	5.47	95	160.5	57	130	86	0.74	0.33	43.9	0.79	Absent	*Bryum* species
70°46′10.2″S 11°47′41.1″E	124	4.85	0.07	0.89	56	13	55	73	33	55	8.87	0.37	0.54	51.2	1.14	*Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis, *Lecanora expectans* Darb.	Absent
70°46′10.5″S 11°49′34.7″E	112	5.96	0.2	0.56	42	22.13	80	152.5	75	80	35.5	1.38	0.43	20.5	1.67	*Buellia grimmiae* Filson, *Caloplaca citrina* (Hoffm.) Th. Fr., *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis, *Acarospora williamsii* Filson, *Lecanora expectans* Darb., *Lecidella siplei* (C. W. Dodge & G. E. Baker) May. Inoue, *Lepraria cacuminum* (A. Massal.) Lohtander.	Absent
70°46′44.6″S 11°51′02.2″E	125	5	0.17	1.29	63	38.53	125	114	56.5	110	53.3	0.4	0.86	58	1.9	*Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Lepraria cacuminum* (A. Massal.) Lohtander	Absent
70°46′44.9″S 11°51′02.2″E	125	5.31	0.2	0.48	14	26	115	136.5	46.5	95	52	0.44	1.33	20.9	2.37	*Buellia grimmiae* Filson, *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis, *Lepraria cacuminum* (A. Massal.) Lohtander, *Caloplaca citrina* (Hoffm.) Th. Fr., *Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Lecanora expectans* Darb., *Lecidella siplei* (C. W. Dodge & G. E. Baker) May. Inoue	Absent

70°47′25.6″S 11°38′02.0″E	405	5.35	0.15	0.3	35	11.97	65	60.5	49.5	60	44.4	0.25	0.49	50.1	1.48	*Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis.	Absent
70°54′32.2″S 12°04′04.1″E	957	4.42	0.53	0.3	42	8.07	67.5	219	28.5	80	62.1	0.56	0.29	22	1.26	*Rinodina olivaceobrunea* C. W. Dodge & G. E. Baker, *Lepraria cacuminum* (A. Massal.) Lohtander Lecidella sp. B, *Candelariella flava* (C. W. Dodge & Baker) Castello & Nimis,	*Bryum archangelicum* Bruch & Schimp, *Orthogrimmia sessitana* (De Not.) Ochyra & Zarnowiec.
	Range	4.42 – 6.80	0.06 – 1.22	0.06 – 1.29	14 – 105	5.46 – 52.85	50 – 355	50.05 –357	16 – 152.5	40 – 297.3	25 –275	0.25 –2.6	0.22 –1.33	14.3 –101	0.79 –6.36		
	Mean	5.69	0.34	0.62	52.95	19.32	116.01	170.17	68.38	102.48	74.8	0.89	0.55	51.16	2.43		
	S.D.	0.60	0.27	0.29	21.06	11.20	59.32	82.70	29.62	54.76	56.30	0.61	0.23	25.56	1.16		

Table 2. Correlation coefficients (r) among different soil parameters

Number	pH	EC	OC	N	P	K	Ca	Mg	Na	Cl	Cu	Zn	Fe	Mn
PH	1	0.498**	NS	NS	NS	0.684**	0.547**	0.750**	0.667**	0.513**	0.552**	NS	NS	0.453*
EC	0.498**	1	NS	NS	NS	0.731**	0.632**	0.436**	0.809**	0.731**	NS	NS	NS	NS
OC	NS	NS	1	0.563**	NS	NS	NS	NS	NS	NS	NS	NS	0.442**	NS
N	NS	NS	0.563**	1	NS	NS	NS	NS	NS	NS	NS	NS	0.393*	NS
P	NS	NS	NS	NS	1	NS	NS	NS	NS	NS	NS	NS	NS	NS
K	0.684**	0.731**	NS	NS	NS	1	0.618**	0.572**	0.899**	0.831**	0.464**	0.346**	NS	0.426*
Ca	0.547**	0.632**	NS	NS	NS	0.618**	1	0.699**	0.659**	0.635**	0.600**	NS	NS	0.528**
Mg	0.750**	0.436*	NS	NS	NS	0.572**	0.699**	1	0.608**	0.502**	0.473**	NS	NS	0.466**
Na	0.667**	0.809**	NS	NS	NS	0.899**	0.659**	0.608**	1.876**	0.876	NS	NS	NS	NS
Cl	0.513**	0.731**	NS	NS	NS	0.831**	0.635**	0.502**	0.876**	1	NS	NS	NS	NS
Cu	0.552**	NS	NS	NS	NS	0.464**	0.445**	0.570**	NS	NS	1	NS	NS	NS
Zn	NS	NS	NS	NS	NS	0.347*	NS	NS	NS	NS	NS	1	NS	NS
Fe	NS	NS	0.441**	0.417*	NS	NS	NS	NS	NS	NS	NS	NS	1	NS
Mn	0.453**	NS	NS	0	NS	0.423*	NS	0.358*	NS	NS	NS	NS	NS	1

** significant at 0.01 level; * significant at 0.05 level.

The inter-relationship among soil parameters is given in Table 2. The correlation studies showed that EC exhibited significant and positive correlation with K (r = 0. 731 * *), Ca (r = 0. 632 * *) , Mg (r = 0. 436 * *), Na (r = 0. 809 * *), chloride (r = 0. 732 * *), Cu 0. 552 * * and Mn content (r = 0. 453 * *). Soil pH also exhibited positive and significant correlation with EC (r = 0. 497 * *), K (r = 0. 684 * *), Ca (r = 0. 547 * *) Mg (r = 0. 750 * *), Na (r = 0. 667 * *), chloride content (r = 0. 513 * *). One of the prominent features of Antarctic soils, and one which shows their relationship with soils in other arid regions of the world, is the high content of soluble salts. These salts consist largely of the sulphates, chlorides, and nitrates of sodium, potassium, magnesium, and calcium and Cl^{-1} is the major anion in Cold Desert soils in the McMurdo Sound vicinity and in noncalcareous Polar Desert soils[12]. None of the micronutrient cations exhibited significant correlation with EC. The correlation coefficient for chlorides was higher with EC (r = 0. 732 * *) than pH (r = 0. 513 *).

Organic carbon content of the soil was positively correlated with N (r = 0. 0. 563 * *) and Fe (r = 0. 0. 442 *) only. The available micronutrient contents depended largely on the organic carbon content in inceptisols[13]. All the macronutrient cations (K, Ca, Mg and Na) and chloride content were positively and significantly correlated among themselves. Potassium exhibited highest correlation with chloride (r = 0. 899 * *) followed by Na (r = 0. 874 * *). Copper and Mn were positively correlated with Ca, Mg and K but not with Na. Inter-relationship among different micronutrient cations were not significant.

No specific pattern was observed with respect to the type of species observed. Concentrations of micronutrients nutrients determined at thirty-four locations did not appear to account for the variations in number of communities and species composition. Mataloni[14] in Cierva Point, the Antarctic Peninsula observed that water content and concentrations of nutrients did not appear to account for the large inter-polygon variation found in species composition and relative frequencies of occurrence. In Vestfold Hills in the Eastern Antarctica soil nutrients were not significantly associated with moss diversity or abundance[15]. Metal-oxide species of Al, Fe, and Mn were more abundant in lichen-dominated environments[16] but in present study it does not show any correlation.

Marine environment is the main source of major ions in lichens and mosses[17,18]. This is also true in Schirmacher Oasis where white-salt depositions were observed on rock surfaces in the study area. The nutrient contents did not relate with the vegetation composition in Schirmacher Oasis. Similar observations were made in Windmill Island, suggesting that nutrient levels are not affected by the vegetation, but by seabird droppings [19].

The available nutrient contents present in different samples in the study area did not appear to limit/affect plant adaptation. The present observations resembles to Windmill Island region of East Antarctica where nutrient availability is a not a limiting factor, whereas microclimate, such as moisture availability, ground-level wind speed, soil surface temperature, availability of light and other geomorphological features together have a primary influence on plant growth[19]. Thus, the microclimate might have affected the lichen and moss community structure and composition in Schirmacher Oasis, East Antarctica.

Acknowledgements Authors are grateful Shailesh Nayak, Secretary, Ministry of Earth Sciences, Govt. of India for support and Dr P. G. Adsule, Director National Research

Centre for Grapes, Pune for analytical facilities.

References

[1] Beyer L, Bolter M (1999): Formation, ecology, and geography of Cryosols of an ice-free oasis in Coastal East Antarctica near Casey Station (Wilkes Land). Australian-Journal of Soil Research, 37(1): 209 -244.

[2] Hazra AK (1994): A study on the population of ecology of soil nematode fauna in relation to some edaphic factors in Schirmacher Oasis. Ninth Indian expedition to Antarctica, Scientific Report, Department of ocean Development, Technical Publication, 6: 65 -90.

[3] Line MA(1988): Microbial flora of some soils of Mawson Base and the Vestfold Hills, Antarctica. Polar-Biology, 8(6): 421 -427.

[4] Smith RIL(1978): Summer and winter concentrations of sodium, potassium and calcium in some maritime Antarctic cryptogams. Journal of Ecology. 66(3): 891 -909.

[5] Ravindra R, Chaturvedi A, Beg MJ (2001): Meltwater lakes of Schirmacher Oasis-their genetic aspects and classification. In Advances in Marine and Antarctic Science, eds. Sahu DB and Pandey PC, Daryaganj, New Delhi, 301 -313.

[6] Walkley A, Black CA(1934): An examination of Degtjareff methods for determining soil organic matter and a proposed modification of chromic acid toleration method. Soil Science. 37: 29 -38.

[7] Subbiah BH, Asija GL(1956): A rapid procedure for determination of available nitrogen in soils. Current Science. 25: 259 -260.

[8] Bray RH, Kurtz LT (1945): Determination of total organic and available forms of phosohorus in soils. Soil Science, 59: 39 -45.

[9] Lindsay WL, Norvell WA(1978): Development of DTPA test for zinc, iron, copper and manganese. Soil Science Society of America proceedings, 42: 421 -428.

[10] Burikins MB, Virginia RA, Wall DH(1999): Organic Carbon cycling in Taylor valley, Antarctica: Quantifying soil resiorvior and soil respiration. Global Change Biology, 7:113 -125.

[11] Ino Y, Oshima Y, Kanda H, Matsuda T (1980): Soil respiration in the vicinity of Syowa Station, Antarctica. Relationships between soil respiration rate and water content or nitrogen content. Antarctic-Record, 70: 31 -39.

[12] Bockheim JG(1980): Properties and classification of some desert soils in coarse-textured glacial drift in the Arctic and Antarctic. Geoderma, 24 (1): 45 -69.

[13] Sharma BD, Harsh Arora, Raj Kumar, Nayyar VK(2004): Relationships between soil characteristics and total and DTPA-extractable micronutrients in Inceptisols of Punjab. Communications-in-Soil-Science-and-Plant-Analysis, 35(5/6): 799 -818.

[14] Mataloni G, Tell G, Wynn-Williams DD (2000): Structure and diversity of soil algal communities from Cierva Point (Antarctic Peninsula). Polar-Biology, 23 (3): 205 -211.

[15] Leishman M, Wild C (2001): Vegetation abundance and diversity in relation to soil nutrients and soil water content in Vestfold Hills, East Antarctica. Antarctic-Science. 13 (2): 126 -134.

[16] Johnston CG, Vestal JR(1989): Distribution of inorganic species in two antarctic cryptoendolithic microbial communities. Geomicrobiology Journal, 7(3): 137 -153.

[17] Beyer L, Bolter M, Seppelt RD (2000): Nutrient and thermal regime, microbial biomass, and vegetation of Antarctic soils in the Windmill Islands region of East Antarctica (Wilkes Land). Arctic, Antarctic, and Alpine Research, 32 (1):30 -39. 18] Bargagli R, Sanchez - Hernandez, JC & Monaci F (1999): Baseline concentrations of elements in the Antarctic macrolichen Umbilicaria decussata. Chemosphere, 38 (3): 475 -487. 19] Bargagli R, Smith RIL, Martella L, Monaci F, Sanchez - Hernandez JC, Ugolini FC (1999): Solution geochemistry and behaviour of major and trace elements during summer in a moss community at Edmonson Point, Victoria Land, Antarctica. Antarctic Science; 11:3 -12.