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Concentrations of Carbon Dioxide and Oxygen in Mole Tunnels

Stężenie dwutlenku węgla i tlenu w korytarzach kreta

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Schaefer V H. & Sadleir R. M. F. S., 1979: Concentrations of carbon dioxide and oxygen in mole tunnels. Acta theriol., 24, 21: 267—271 [With 2 Tables].

Air samples were collected from mole (*Scapanus orarius* True, 1896) runs and in adjacent soil at two week intervals over a four month period and examined for CO_2 and O_2 content. Oxygen and CO_2 concentrations in mole tunnels were highly correlated with those of the soil air. Oxygen was consistently higher; and CO_2 consistently lower, in mole runs, indicating a degree of aeration in the runs. The gas concentrations of runways and soil air were correlated with soil moisture content — CO_2 increasing and O_2 decreasing in the tunnels with increasing moisture. Carbon dioxide reached a maximum tunnel concentration of 5.5% and O_2 a minimum of 14.3%. Molehill construction rates were not related to either CO_2 or O_2 concentrations.

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1. INTRODUCTION

Moles live in a network of tunnels, usually at depths of 10—30 cm and normally come above ground only to disperse (Glendenning, 1959; Mellanby, 1971; Quilliam, 1966; Southern, 1954), or under unusual cirumstances such as drought (Morris, 1966).

The atmosphere of mole runs could be expected to be high in carbon dioxide and low in oxygen. Quiliam *et al.* (1971) speculated that the average carbon dioxide content of the soil air would be 50 times that of atmospheric or as high as 5% in mole tunnels. Such levels could pose a respiratory problem to moles, considering their small size and the physiologically demanding work of tunnel digging.

The European Mole (*Talpa europaea* Linnaeus, 1758) is known to have respiratory adaptations to its environment. Koržujev & Koreckaja (1962) have reported that, in comparison to similarly sized mammals, the European Mole has twice as much blood and twice as much haemoglobin. The serological composition of the blood is also adaptive in showing many similarities to that of humans acclimatized to high altitudes (Dąbrowski & Skoczeń, 1962; Quilliam *et al.* 1971).

This note describes oxygen and carbon dioxide concentrations inside mole runs and the adjacent soil. Mole activity, as defined by the numbers of molehills, was also monitored to see if it was in any way related to the nature of the tunnel or soil air.

2. METHODS

The territories of three coast moles (*Scapanus orarius* True, 1896) were located by examining the hill distribution in a pasture near Maple Ridge, B. C. The areas of the three territories were 1,050, 1,350, and 1,250 m^2. Tygon tubing (O.D.=5/32". I.D.=3/32") was placed into mole runs by digging into a mole hill, inserting one end of the tubing into the run underneath, covering the hole with earth, and plugging the exposed end of tubing. Ten such sample tubes were placed into each territory in an approximately uniform distribution. The average depths of the tubes in each territory were: 13.3 cm, 11.7 cm, and 12.2 cm.

At a 1 m distance from five of the sample sites in each territory we burried an inverted 5×10 cm clay pot at a depth of 15 cm, thus creating an air space. Tygon tubing led from the pot to the surface. Soil air samples were collected from this space.

Air samples were collected through the tubing with 30 cc plastic disposable syringes at approximately two-week intervals from April to August 1977. A 20 cc volume of air was first extracted and discarded to clear the sample tube, then 5 cc more were discarded to clear the needle; finally an air sample of 30 cc was extracted for analysis. The air samples were brought back to the laboratory and their O_2 and CO_2 concentrations determined to an accuracy of 0.1% using a Med-spect 1 medical mass spectrometer (samples were directly injected into the uptake flow). All samples were collected between 0750 and 1000 hours, and were analyzed within four hours. Appreciable loss of CO_2 through the plastic of the syringes does not occur before six hours (Consolazio, 1963).

Molehills were counted on the territories the day before the air samples were collected. Any mounds or column of earth pushed to the surface by moles were counted. Five soil samples were also collected at a depth of 10 cm from each territory on the day of the counts for soil moisture and pH measurements.

3. RESULTS

The average concentrations of the gases in the tunnels varied from 0.3—2.2% for CO_2 and 16.8—20.4% for O_2 (Table 1). In the soil air, CO_2

Table 1

The rate of molehill construction, gas concentrations, soil moisture, and pH values obtained for the bi-weekly samples for the three mole territories combined. Soil moisture and pH were calculated on the basis of 15 samples for each date.

Date	Mean No. of hills per day	Concentration of gases in runways (%)			Concentration of gases in soil (%)			Soil moisture (%)	pH
		n	O_2	CO_2	n	O_2	CO_2		
25/4	10.26	30	17.7 ± 1.4*	2.2 ± 1.0				38.7 ± 9.3	4.71 ± 0.30
04/5	12.78	28	17.8 ± 1.5	2.1 ± 1.1	15	15.4 ± 3.0	3.7 ± 1.8	42.2 ± 6.5	4.70 ± 0.27
16/5	14.83	28	18.8 ± 1.1	1.9 ± 1.0	14	16.9 ± 2.9	3.7 ± 1.8	38.0 ± 6.0	4.86 ± 0.31
01/6	8.69	28	16.8 ± 1.7	2.8 ± 1.4	12	12.2 ± 3.4	5.5 ± 2.8	45.0 ± 6.5	4.75 ± 0.25
20/6	4.74	27	19.8 ± 0.4	0.6 ± 0.4	9	19.2 ± 0.6	1.5 ± 0.8	18.0 ± 2.5	4.68 ± 0.27
04/7	10.36	28	19.9 ± 0.3	0.9 ± 0.4	14	19.4 ± 0.7	1.4 ± 0.8	32.0 ± 7.7	4.87 ± 0.41
18/7	10.71	26	19.7 ± 0.6	1.0 ± 0.6	14	18.9 ± 1.4	1.7 ± 1.2	26.7 ± 6.1	4.63 ± 0.28
01/8	6.29	21	20.4 ± 0.3	0.5 ± 0.3	14	20.0 ± 0.7	0.9 ± 0.7	21.4 ± 4.9	4.77 ± 0.28
18/8	1.89	26	20.3 ± 0.5	0.3 ± 0.4	15	20.1 ± 0.8	0.5 ± 0.7	14.4 ± 3.5	4.56 ± 0.23
29/8	9.50							26.8 ± 6.1	4.72 ± 0.12

* X ± 1 S.D.

varied from 0.5—5.5% and O_2 from 12.2—20.1%. The maximum level of CO_2 found in any individual tunnel sample was 5.5% and the minimum O_2 concentration was 14.3%. For the soil air samples the maximum level of CO_2 was 11.3% and the minimum for O_2 was 5.2%.

The average number of molehills per day between sampling periods correlated significantly with both the average soil pH and moisture for the territories combined (Table 2). The relationships between the tunnel

Table 2

Correlations among the number of molehills, gas concentrations, and soil pH and moisture in three mole territories. Sample sizes are included in brackets.

Character	Number of molehills	O_2 in tunnels	CO_2 in tunnels	O_2 in soil	CO_2 in soil	pH
O_2 in tunnels	−0.25 (27)					
CO_2 in tunnels	0.16 (27)	−0.96 ** (241)				
O_2 in soil	−0.08 (23)	0.78 ** (100)	−0.75 ** (100)			
CO_2 in soil	0.12 (23)	−0.76 ** (100)	0.79 ** (100)	−0.87 ** (107)		
pH	0.69** (30)	0.16 (102)	−0.15 (102)	−0.16 (47)	−0.22 (47)	
Soil moisture	0.40 * (30)	−0.67 ** (102)	0.65 ** (102)	−0.70 ** (102)	0.79 ** (47)	0.10 (102)

* $p < .05$; ** $p < .01$.

and soil gas concentrations (in percentages) and the coefficient of determination for each are: CO_2 in tunnel $= -0.72$ O_2 in tunnel $+15.17$ (93%); CO_2 in tunnel$=0.40$ CO_2 in soil$+0.35$ (62%); O_2 in tunnel$=0.33$ O_2 in soil$+13.31$ (61%), and; CO_2 in soil$=-0.55$ O_2 soil$+12.22$ (76%).

The O_2 and CO_2 contents of both the tunnel and soil air were significantly related to soil moisture. The relationships between them and the coefficient of determination for each are: O_2 in tunnel$=-0.08$ soil moisture$+21.80$ (45%); CO_2 in tunnel$=0.06$ soil moisture -0.67 (42%); O_2 in soil$=-0.19$ soil moisture $+23.82$ (48%), and; CO_2 in soil$=0.12$ soil moisture — 1.75 (62%). There were no significant relationships between any of the gas concentrations and soil pH.

4. DISCUSSION

The CO_2 levels in mole runs is high, averaging more than 10 times that of atmospheric, reaching 200 times that of atmospheric in individual samples. Oxygen concentrations are inversely reduced. The levels found in this study would normally be exaggerated for the moles in the deeper runs away from hills since there would be less aeration (Olszewski & Skoczeń, 1965).

The CO_2 levels are approximately twice as great in the soil air as compared to the mole runs. This clearly indicates how well mole hills aerate the tunnels. The levels of the gases in the soil air and the runways, however, were very strongly correlated and predictable from each other. Thus it would seem that while the runways are being aerated, the concentrations of CO_2 and O_2 therein are still strongly influenced by the concentrations of CO_2 and O_2 in the soil air.

The CO_2 contents of both the soil and tunnel air rise with increasing soil moisture. This is probably due to changes in soil air space (Buckman & Brady, 1969). As soil moisture increases, the total soil air space decreases, and there is less diffusion of the soil gases into the atmosphere. As soil air space increases with decreasing soil moisture, there is an almost free exchange of gases and their concentrations approach equality.

This study shows that mole tunnels are aerated to a certain degree. Olszewski & Skoczeń (1965) suggested that this was due partly to air movements around molehills. However molehills result primarily from the tunnelling habits of moles (Mellanby, 1971), and are perhaps only secondarily important in aerating the runs. The correlations between the numbers of molehills and the gas concentrations were insignificant. At greater extremes of gas concentrations the relationships may become significant. Alternatively, moles may simply leave the areas concerned because of respiratory difficulty, or for other reasons such as the ground becoming too wet to support earthworms.

The levels of oxygen and carbon dioxide found here in mole runs illustrates for the first time the gaseous environment to which moles must adapt while living underground. Not only must moles possess the physiological adaptations to the low partial pressures of oxygen as mentioned in the introduction, they must also be adapted to high levels of carbon dioxide, possibly through an increase in the chemoreceptor drive of ventilation due to both hypoxia and hypercapnia (Dejours, 1975).

The correlations of molehill numbers with soil moisture and pH is likely due to the effect of these soils characters on digging activity of the coast mole. Moles dig more when it is easier for them to dig, and hence push up more hills when the ground is wet (Schaefer, 1978). The weights of earthworms, the coast mole's chief food source (Glendenning, 1959) are positively related to soil pH, and moles dig more as earthworm weights increase.

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Vocalization of the Shrews *Suncus etruscus* and *Crocidura russula* during Normothermia and Torpor

Głosy ryjówek: *Suncus etruscus* i *Crocidura russula*, przy normotermii i odrętwieniu

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Hutterer R., Vogel P., Frey H. & Genoud M., 1979: Vocalization of the shrews *Suncus etruscus* and *Crocidura russula* during normothermia and torpor. Acta theriol. 24, 21: 271—276 [With 1 Table & 2 Figs.].

The vocalization of the shrews *Suncus etruscus* and *Crocidura russula* during normothermia and torpor is investigated. While frequency and call duration are independent of body temperature, the tremolo structure shows a spreading correlated with falling body temperature. The particular calls emitted during torpor are defence calls, modified by merely physiological factors. Their main function might be of intraspecific nature.

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INTRODUCTION

Torpor in shrews was first demonstrated for *Suncus etruscus* (Vogel, 1974) and since then observed in several species of *Crocidurinae* (Nagel, 1977; Frey & Vogel, 1979). There is also some evidence for the occurrence of torpor in three species of *Soricinae* (Wolf, 1954; Lindstedt, 1977; Newman & Rudd, 1978).

During torpor shrews stay immobile in the nest. When disturbed, they utter harsh shrieking calls (Vogel, 1974). This behaviour is the same in all shrew species in which torpor has been observed. The shrieking calls are clearly distinct from the vocal repertoire of normothermic animals. It is therefore of a certain interest to study these calls, especially the effect of body temperature on the form and frequency