STUDIA FORESTALIA SUECICA

Nr 140 · 1977

Effects of nitrogen fertilization on the abundance of enchytraeids and micro-arthropods in Scots pine forests

Effekter av kvävegödsling på abundansen av enchytraeider och mikroartropoder i tallskog

ULRIK LOHM, HELÉNE LUNDKVIST, TRYGGVE PERSSON and ANDERS WIRÉN

Institute of Zoology,
Uppsala University, Sweden

SKOGSHÖGSKOLAN

SWEDISH COLLEGE OF FORESTRY

STOCKHOLM

Abstract

ODC 114.67:237.4

The effect on the abundance of enchytraeids and microarthropods of the nitrogen fertilizers, ammonium nitrate and urea, was studied. The experimental sites were three Scots pine stands in central and northern Sweden. Doses of fertilizers were similar to those used in practical forestry in Sweden but the effects of different doses of ammonium nitrate were also investigated.

A significant decrease in the abundance of Enchytraeidae, Collembola and Cryptostigmata after ammonium nitrate fertilization was observed in one of the experiments. On the basis of this study and previous investigations, the following patterns of response to nitrogen fertilizers are discussed: 1) A short-term effect with decreased abundance owing to ammonium toxicity or a "salt effect". 2) A long-term effect with increasing abundance resulting from increased food supply.

Ms. received 3rd May, 1977

LiberFörlag/Allmänna Förlaget
ISBN 91-38-03733-5, ISSN 0039-3150
Berlings, Lund 1977

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Introduction

The rate of wood production in northern coniferous forests is markedly increased by nitrogen fertilization (Tamm 1964). In Sweden forest fertilization on a practical scale started in the early 1960s. During the period 1962—75, approximately one million hectares of coniferous forest in Sweden were fertilized with nitrogen (Holmen 1976). The mean dosage was increased from 61 kg nitrogen per hectare in 1962 to 148 kg in 1975 (Friberg 1971; Holmen *op. cit.*). Initially nitrogen was usually applied as urea, but the use of ammonium nitrate gradually increased. In 1974 and 1975 the percentages of nitrogen applied as ammonium nitrate were 68 and 80 %, respectively.

The effects of nitrogen fertilization on the soil system and especially on the soil organisms are poorly known. It is often assumed that nitrogen fertilization stimulates the growth of microorganisms and thus, indirectly, the soil fauna feeding on them. Several authors have found increased abundance of soil animals after moderate fertilization (cf. Hill *et al.* 1975), but other responses of the soil fauna have also been observed.

Huhta *et al.* (1967; 1969) recorded a reduction in soil animal numbers during the first year after NPK-treatment equivalent to 90 kg N ha^{-1}. During the second and third years the abundance increased, especially in the case of Enchytraeidae and Collembola. Abrahamsen (1970) also found an initial reduction in the abundance of the enchytraeid *Cognettia sphagnetorum* after fertilization with urea equivalent to 400 kg N ha^{-1}. Two to three years later the abundance increased and became higher than in the control plots. With urea corresponding to 100 kg N ha^{-1} no marked effects were observed.

Several factors may influence the effects of nitrogen fertilization on the abundance of soil animals, e.g. dosage, time after application and type of fertilizer. The aim of the present study was to assess the effects on the abundance of enchytraeids and microarthropods from: 1) different dosages of ammonium nitrate; 2) ammonium nitrate at the most commonly used dose in practical forestry at different times after fertilization; and 3) urea in the dose used in practical forestry. A preliminary report on the first part of the study was given in Axelsson *et al.* (1973).

Study areas

Three Scots pine stands, with established fertilizer experiments, were chosen for this study. The experimental design was randomized blocks. The number of blocks, location and some stand data are shown in Table 1. The three stands were at Lisselbo, Locksta and Hedemora.

Lisselbo is in Gästrikland about 25 km SW of Gävle. The experiment (Lisselbo E 40) is one in a series of optimum nutrition experiments described by Tamm *et al.* (1974). Fertilizer was applied yearly in three different dosages. Two types of treatment (N1 and N3) and the control (O) were chosen for our study. In N1 the dosages were 60 kg N ha^{-1} in the first and second year and 40 kg N ha^{-1} in the third. The dosages in N3 were three times those in N1 (Fig. 1).

Locksta is situated about 60 km NW of Örnsköldsvik. The Locksta 7101:1 experiment is described in Jonsson (1976). Fertilizer was applied in 1971 as ammonium nitrate corresponding to 150 kg N ha^{-1} (AN) (Fig. 1).

The third site, Hedemora 7303, is situated in Dalarna between Hedemora and Avesta. This experiment is described in Möller and Rosvall (1976). The present study compared soil mesofauna in treatment with urea (U) and ammonium nitrate (AN) with that in the untreated control plots (O). The dosage was 150 kg N ha^{-1} in both cases (Fig. 1).

Table 1. Site properties and location of investigated Scots pine stands.

	Lisselbo E 40	Locksta 7101:1	Hedemora 7303	
	Block 1—4	Block 1—9	Block 1	Block 2—3
Latitude	60°28′	63°47′	60°12′	
Longitude	16°57′	18°26′	16°15′	
Altitude (m.a.s.l.)	80	250	140	
Soil material	Fine sand-gravel	Sand-gravel	Sand	Sand-gravel
Soil type	Intermediate iron podzol	Intermediate iron podzol	Intermediate iron podzol	Intermediate iron podzol
Forest type (Arnborg)	Dry dwarf-shrub	Dry dwarf-shrub	Mesic to dry dwarf-shrub	Dry dwarf-shrub
No. of trees per hectare	1200	530	700	1050
Age of stand at sampling (years)	16	~75	~100	59

Methods

Sampling occasions and their relation to the dates of fertilizer application are shown in Fig. 1. The sampling at Lisselbo was carried out in October 1971, i.e. five months after the latest fertilizer treatment. Five sampling units were selected at random within each of the treatment plots O, N1 and N3. The number of sampling units for microarthropods was reduced to four in N3 because of limited extraction capacity. At Locksta the sampling of enchytraeids and microarthropods was performed two and three years, respectively, after treatment. On these occasions three sampling units were selected at random in each plot. The Hedemora plots were sampled ten months after fertilizer treatment and five sampling units per plot were selected at random.

The enchytraeids were sampled with a soil corer with an area of 33.2 cm². The cores were taken to a depth of about 15 cm and divided into three soil layers: litter and humus, bleached soil layer and mineral soil layer. The enchytraeids were extracted with a modified Baermann funnel technique (O'Connor 1962) and identified according to Nielsen and Christensen (1959).

The microarthropods were sampled to a depth of 10 to 12 cm. The area of the corer was 10.8 cm². The soil cores were brought intact to the laboratory where they were divided into 2-cm thick slices and extracted in an extractor of "Macfadyen high gradient canister"-type (Macfadyen 1961). The collembolans were identified to species level according to Gisin (1960) and Palissa (1964; 1966). Routine counting was simplified by combining *Onychiurus* spp. of the *armatus*-group under the name *O. armatus* Tullb.

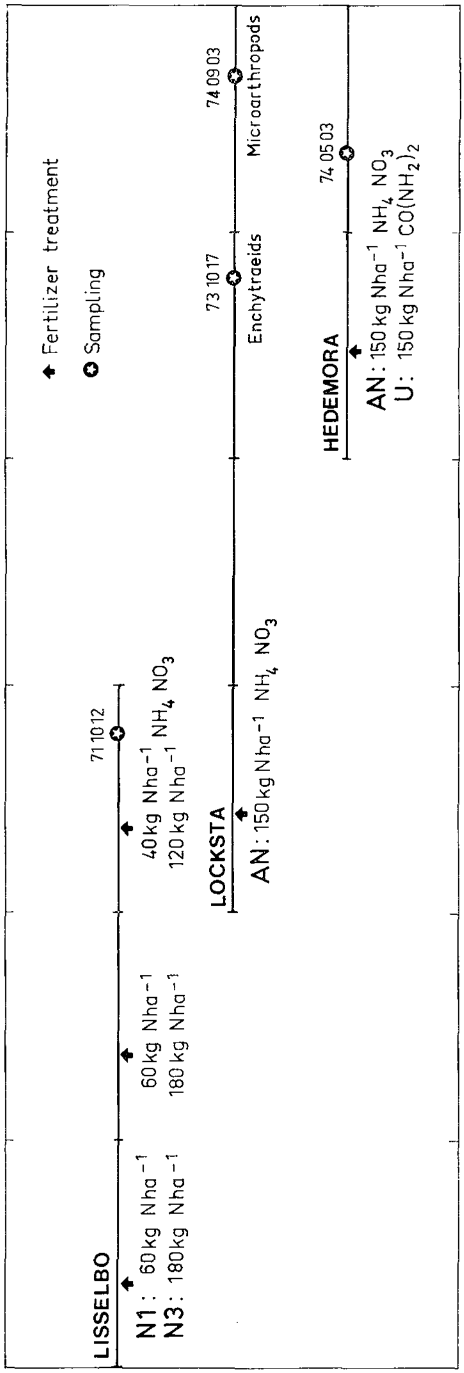

Figure 1. Sampling dates in relation to fertilizer application. Doses and types of fertilizers are also shown.

For the same reason *Folsomia litsteri* and *F. fimetarioides* were treated as one category. Acari was separated into Mesostigmata, Prostigmata, Astigmata and Cryptostigmata. Mesostigmata was furthermore separated into Gamasina and Uropodina. Some groups among the Cryptostigmata were selected for separate counting.

Results

Estimates of the abundance of enchytraeids and microarthropods under different treatment are given in Tables 2—4. Significant differences between the types of treatment are indicated in the tables. Total abundances of different groups are summarized in Fig. 2.

The enchytraeid fauna at all three sites was dominated by *Cognettia sphagnetorum*. At Lisselbo this dominance was almost complete while at Hedemora, *C. sphagnetorum* dominated to 97, 97 and 93 % in control, ammonium nitrate and urea plots, respectively. The other enchytraeid species found in low numbers belonged to the genus *Mesenchytraeus*. A significant difference between treated and untreated plots was found at Lisselbo, where the abundance of *C. sphagnetorum* in N3 was significantly lower than in control and N1 (Table 2). At Hedemora and Locksta no significant differences were observed (Tables 3 and 4).

The abundance of Collembola and Cryptostigmata at Lisselbo had decreased after the N3-treatment. With one exception, where there was a decrease in the springtail *Orchesella bifasciata*, no effect of the N1-treatment was observed (Table 2). *O. bifasciata* was also affected by the N3-treatment. Other Collembola species with lower abundance in the N3-treatment than in the control were *Tullbergia krausbaueri*, *Anurophorus septentrionalis* and *Isotomiella minor*. These species were among the most abundant at the investigated sites (Tables 2—4). Among the groups selected for separate counting within Cryptostigmata, only the adults of the genus *Oppia* showed a significant decrease (Table 2).

No significant differences were observed in the experiments with 150 kg N ha^{-1} of ammonium nitrate or urea (Table 4) applied ten months before sampling (Hedemora). In the experiment with 150 kg N ha^{-1} as ammonium nitrate applied about three years before sampling (Locksta), the only detectable difference was a decrease in the number of the springtail *Anurophorus septentrionalis* (Table 3).

Table 2. Mean number per m^2 with standard error (s.e.) of enchytraeids and microarthropods in October 1971 at Lisselbo. A significant difference between types of treatment is indicated with the treatment codes and *($p<0.05$) or **($p<0.01$). For explanation of treatment code, see Fig. 1 and text.

	Treat-ment	Mean	s.e	Significant difference
ENCHYTRAEIDAE				
Cognettia sphagnetorum Vejd.	O	6400	1400	O—N3*
	N1	6300	760	N1—N3*
	N3	1100	120	
Mesenchytraeus sp.	O	15	15	
	N1	0		
	N3	0		
Enchytraeidae, total	O	6400	1400	O—N3*
	N1	6300	760	N1—N3*
	N3	1100	120	
COLLEMBOLA				
Willemia anophthalma Börn.	O	320	320	
	N1	280	280	
	N3	0		
Friesea mirabilis Tullb.	O	370	370	
	N1	280	93	
	N3	170	110	
Anurida pygmaea Börn.	O	4500	770	
	N1	5200	1500	
	N3	5200	1200	
Neanura muscorum Templ.	O	420	210	
	N1	420	46	
	N3	690	550	
Onychiurus absoloni Börn.	O	190	130	
	N1	0		
	N3	0		
Onychiurus armatus Tullb.	O	17000	7200	
	N1	8500	2300	
	N3	6400	2300	
Tullbergia krausbaueri Börn.	O	44000	12000	O—N3*
	N1	25000	4700	
	N3	12000	2500	
Anurophorus septentrionalis Palissa	O	5300	2700	O—N3*
	N1	600	600	
	N3	350	220	
Anurophorus binoculatus Ksen.	O	0		
	N1	93	93	
	N3	0		
Folsomia quadrioculata Tullb.	O	3200	2500	
	N1	6400	2100	
	N3	750	440	
Isotomiella minor Schäff.	O	5200	1800	O—N3*
	N1	1300	600	
	N3	870	150	
Isotoma violacea Tullb.	O	46	46	
	N1	93	93	
	N3	0		
Entomobrya nivalis L.	O	46	46	
	N1	46	46	
	N3	0		

	Treat-ment	Mean	s.e.	Significant difference
Orchesella bifasciata Nic.	O	1500	500	O—N3*
	N1	320	200	
	N3	230	0	
Lepidocyrtus lignorum Fabr.	O	230	140	
	N1	370	130	
	N3	580	120	
Entomobryidae spp. (juv.)	O	324	46	
	N1	93	53	
	N3	350	150	
Dicyrtoma fusca Luc.	O	0		
	N1	46	46	
	N3	0		
Collembola, total	O	83000	17000	O—N3**
	N1	49000	6900	
	N3	28000	3500	
PROTURA				
Eosentomon spp.	O	14000	3200	
	N1	18000	4500	
	N3	5400	1400	
SYMPHYLA				
Symphylellopsis sp.	O	190	130	
	N1	370	200	
	N3	58	58	
ACARI				
Mesostigmata (Gamasina) spp.	O	5300	1300	
	N1	8100	620	
	N3	5300	1400	
Mesostigmata (Uropodina) spp.	O	0		
	N1	140	89	
	N3	58	58	
Prostigmata spp.	O	36000	3200	
	N1	33000	6300	
	N3	40000	9200	
Astigmata spp.	O	2200	750	
	N1	7600	1200	
	N3	1600	570	
Euptyctima spp.	O	1000	220	
	N1	2500	1100	
	N3	1300	240	
Brachychthoniidae spp.	O	62000	9400	
	N1	81000	18000	
	N3	48000	13000	
Camisiidae spp.	O	7800	1400	
	N1	5600	2600	
	N3	2800	1700	
Tectocepheus velatus Mich.	O	43000	9500	
	N1	34000	14000	
	N3	33000	9400	
Oppia spp. (adults)	O	55000	13000	O—N3*
	N1	37000	6300	
	N3	23000	1900	
Scheloribates spp. (adults)	O	1800	1300	
	N1	230	230	
	N3	0		

	Treatment	Mean	s.e.	Significant difference
Cryptostigmata, total	O	280000	24000	O—N3*
	N1	250000	26000	
	N3	190000	20000	
Acari, total	O	330000	28000	
	N1	300000	32000	
	N3	230000	21000	

Table 3. Mean number per m^2 with standard error (s.e.) of enchytraeids (October 1973) and microarthropods (September 1974) at Locksta. A significant difference between types of treatment is indicated with the treatment symbols and *($p<0.05$). For explanation of treatment code, see Fig. 1 and text.

	Treatment	Mean	s.e.	Significant difference
ENCHYTRAEIDAE				
Cognettia sphagnetorum Vejd.	O	3400	1200	
	AN	4300	680	
Enchytraeidae, total	O	3400	1200	
	AN	4300	680	
COLLEMBOLA				
Willemia anophthalma Börn.	O	4800	1500	
	AN	4700	1800	
Friesea mirabilis Tullb.	O	68	45	
	AN	68	45	
Anurida pygmaea Börn.	O	3400	570	
	AN	3000	1200	
Anurida forsslundi Gisin	O	34	34	
	AN	68	45	
Neanura muscorum Templ.	O	170	54	
	AN	170	100	
Onychiurus absoloni Börn.	O	1300	830	
	AN	1700	770	
Onychiurus armatus Tullb.	O	34	34	
	AN	100	72	
Tullbergia krausbaueri Börn.	O	29000	4300	
	AN	20000	7800	
Tetracanthella wahlgreni Axels.	O	720	510	
	AN	140	140	
Anurophorus septentrionalis Palissa	O	4600	500	O—AN*
	AN	3200	450	
Anurophorus binoculatus Ksen.	O	170	170	
	AN	100	72	
Folsomia litsteri Bagn. and	O	2200	1300	
F. fimetarioides Axels.	AN	2700	1700	
Isotomiella minor Schäff.	O	8900	1100	
	AN	5600	1000	
Isotoma viridis Bourl.	O	310	130	
	AN	550	180	
Lepidocyrtus lignorum Fabr.	O	140	54	
	AN	140	74	

	Treat-ment	Mean	s.e.	Significant difference
Tomocerus flavescens Tullb.	O	0		
	AN	68	68	
Megalothorax minimus Willem	O	550	200	
	AN	510	260	
Collembola, total	O	56000	6100	
	AN	42000	9800	
PROTURA				
Eosentomon spp.	O	2500	680	
	AN	2600	930	
ACARI				
Mesostigmata (Gamasina) spp.	O	10000	1400	
	AN	8800	1100	
Prostigmata spp.	O	84000	6400	
	AN	82000	14000	
Astigmata spp.	O	49000	16000	
	AN	25000	8800	
Euptyctima spp.	O	1800	530	
	AN	1500	480	
Brachychthoniidae spp.	O	93000	14000	
	AN	91000	12000	
Carabodes spp.	O	8800	1200	
	AN	10000	1200	
Tectocepheus velatus Mich.	O	130000	24000	
	AN	85000	17000	
Cryptostigmata, total	O	270000	29000	
	AN	240000	20000	
Acari, total	O	420000	35000	
	AN	360000	37000	

Table 4. Mean number per m^2 with standard error (s.e.) of enchytraeids and micro-arthropods in May 1974 at Hedemora. No significant differences between types of treatment were found. For explanation of treatment code, see Fig. 1 and text.

	Treat-ment	Mean	s.e.
ENCHYTRAEIDAE			
Cognettia sphagnetorum Vejd.	O	9200	770
	U	7300	2100
	AN	6600	1200
Mesenchytraeus spp.	O	280	250
	U	540	480
	AN	200	170
Enchytraeidae, total	O	9500	830
	U	7900	1600
	AN	6800	1400
COLLEMBOLA			
Willemia anophthalma Börn.	O	3600	910
	U	15000	13000
	AN	1100	490

	Treatment	Mean	s.e.
Friesea mirabilis Tullb.	O	550	550
	U	250	250
	AN	310	160
Anurida pygmaea Börn.	O	6100	2000
	U	1500	440
	AN	7900	2800
Neanura muscorum Templ.	O	180	110
	U	0	
	AN	0	
Onychiurus absoloni Börn.	O	430	340
	U	490	61
	AN	250	160
Onychiurus armatus Tullb.	O	120	120
	U	0	
	AN	61	61
Tullbergia krausbaueri Börn.	O	21000	4000
	U	23000	4100
	AN	34000	22000
Anurophorus septentrionalis Palissa	O	980	440
	U	740	280
	AN	980	220
Folsomia litsteri Bagn. and F. fimetarioides Axels.	O	370	210
	U	180	180
	AN	1400	1400
Isotomiella minor Schäff.	O	8500	2400
	U	6100	2000
	AN	3500	950
Isotoma viridis Bourl.	O	180	180
	U	1400	1400
	AN	61	61
Lepidocyrtus lignorum Fabr.	O	120	120
	U	0	
	AN	61	61
Tomocerus flavescens Tullb.	O	61	61
	U	310	61
	AN	61	61
Orchesella bifasciata Nic.	O	180	180
	U	120	120
	AN	0	
Megalothorax minimus Willem.	O	0	
	U	0	
	AN	180	110
Collembola, total	O	43000	7500
	U	49000	13000
	AN	50000	27000
PROTURA			
Eosentomon spp.	O	1000	440
	U	1600	970
	AN	980	890
SYMPHYLA			
Symphylellopsis sp.	O	61	61
	U	180	110
	AN	0	

	Treat-ment	Mean	s.e.
ACARI			
Mesostigmata (Gamasina) spp.	O	6900	1800
	U	4800	1200
	AN	4700	370
Mesostigmata (Uropodina) spp.	O	1400	1100
	U	680	220
	AN	250	250
Prostigmata spp.	O	110000	22000
	U	160000	48000
	AN	160000	30000
Astigmata spp.	O	9200	3500
	U	7100	2400
	AN	26000	17000
Euptyctima spp.	O	1700	0
	U	860	270
	AN	2200	480
Carabodes spp.	O	7100	1600
	U	8700	1800
	AN	10000	4000
Tectocepheus velatus Mich.	O	200000	47000
	U	170000	27000
	AN	200000	51000
Cryptostigmata, total	O	530000	110000
	U	530000	150000
	AN	640000	220000
Acari, total	O	650000	130000
	U	700000	190000
	AN	830000	260000

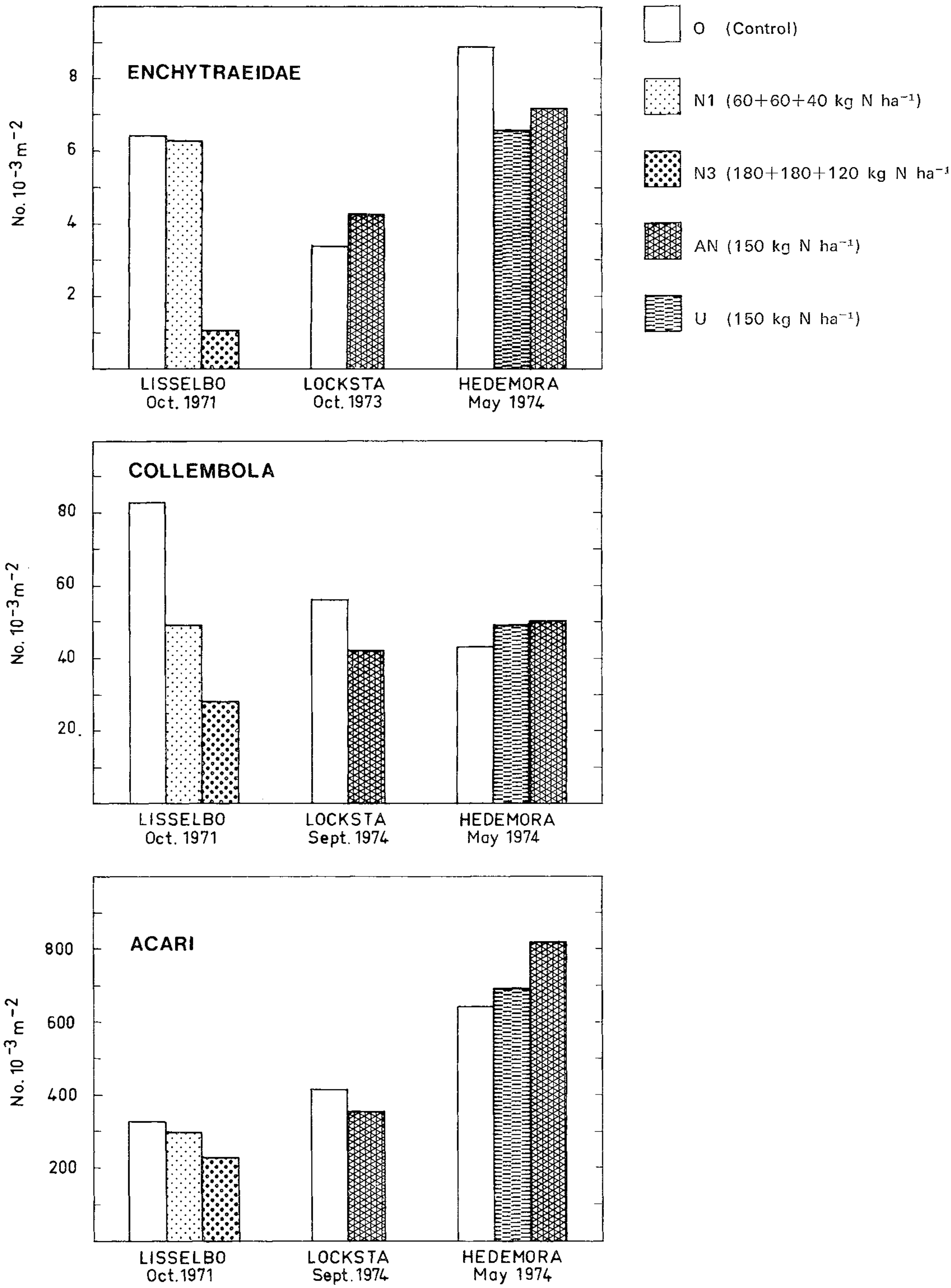

Figure 2. Estimated total abundance of enchytraeids and microarthropods in different types of treatment.

Discussion

The single dose of ammonium nitrate at Hedemora and the yearly dose in the N3 treatment at Lisselbo were similar, but an abundance decrease was observed only at Lisselbo. Precipitation data approximated from nearby meteorological stations (Table 5) indicate that Lisselbo was rather dry at the time of fertilization in 1970 and 1971. The osmotic potential caused by the fertilizer probably had an adverse effect on the fauna. At Hedemora the spring of 1973 was rather wet compared with the conditions at Lisselbo. At the Locksta experiment 2—3 years after the fertilizer application no difference was observed in the abundance of soil fauna, although a long-term increase was expected as a result of increased litterfall (cf. below).

Based on the present and previous studies (e.g. Ronde *et al.* 1958; Huhta *et al.* 1969; Abrahamsen 1970; Marshall 1974) on the effect of nitrogen fertilization on soil fauna populations the following pattern could be recognized: 1) a short-term effect with decreased abundance after fertilizer application and 2) a long-term effect with a gradually increasing abundance after fertilizer application and with maximum abundance after some years. In some cases only one of these effects was observed.

The decrease according to 1) has been observed after application of different types of fertilizers. Different situations may be explained in different ways but two general mechanisms have been suggested: the toxic effect of ammonium and a so-called salt-effect, resulting from the increased osmotic potential in the soil solution.

Among the most commonly used fertilizers are those where ammonium is either a direct component or where ammonium is formed upon hydrolysis (urea). In unionized form (NH_3) it is known to be toxic to most organisms (Warren 1962) and to be very toxic to microarthropods (Moursi 1962, 1970). However, in an acid coniferous forest soil, the amount of ammonium in unionized form is very low when fertilizers such as ammonium nitrate are used. Urea will raise the pH during its hydrolysis. In the Hedemora experiment, for example, the pH was 6.5 in the litter layer one month after urea application compared with 4.7 in

Table 5. Precipitation in mm at the investigated sites for the period April—July of the years when fertilizer was applied. Most of the data represent interpolations between values measured at official meteorological stations. Average yearly precipitation about 600 mm at all sites.

Site	Year	Month	Precipitation (mm)
Lisselbo	1969	April	50
		May	40
		June	15
		July	55
	1970	April	70
		May	25
		June	15
		July	110
	1971[1]	April	17
		May	9
		June	34
		July	90
Locksta[2]	1971	April	30
		May	40
		June	30
		July	40
Hedemora[3]	1973	April	13
		May	50
		June	40
		July	136

[1] Precipitation measured at the site.
[2] 20 mm from the time of application 1971-06-07 and 3 weeks onwards measured at the site (Jonsson 1976).
[3] Precipitation measured about 1 km from the site (Möller and Rosvall 1976).

the control. The change in pH was less pronounced in the humus layer and was insignificant in the mineral soil (Möller and Rosvall 1976). Even at pH 6.5 about 0.3 % of the ammonium (pK = 9.02) would be unionized. On the other hand, the urea-grains could create microsites with much higher pH during hydrolysis, and where even ammonia volatilazation would be possible, at least in combination with low precipitation during the application period (Overrein and Moe, 1967).

The osmotic potential in the soil solution changes as the fertilizer dissolves. Low soil water content in combination with fertilizer application results in high osmotic potential. The hydrophilous members of the soil fauna should be the most sensitive ones and Blake (1961) found that nematodes ceased to move and shrank at pH 4—4.5. Arthropods in general would be less in contact with the soil solution and also more protected by their cuticle, but during moulting, for example, they could still be sensitive. A short-term toxic effect of nitrogen fertilizer is most easily explained by the "salt-effect" hypothesis but occasionally (cf. above) other reactions in the soil could cause the effect. The time of recovery for a particular animal population will differ with fertilizer dosage, precipitation, "sensitivity" of the animal and reproductive rate, where the three former factors will for the most part determine the depth of the abundance decrease.

The long-term effect of N-fertilization on soil fauna is explained by effects on the microorganisms that serve as their food. The increase is firstly a direct response to the fertilizer and secondly a response to the increased litter input from the vegetation after fertilization. A rapid positive response to fertilization has been demonstrated for bacteria by Roberge and Knowles (1966); Mai and Fiedler (1970) and Weetman *et al.* (1972) and for fungal populations by Roberge and Knowles *(op. cit.)*. Schalin (1967) found that fungi increased after urea fertilization as long as the pH did not exceed 4.3, above which bacteria increased and fungi decreased.

The rate and magnitude of the increase in bacterial and fungal populations, respectively, are dependent not only on pH and the dose of nitrogen but also on the amount of available organic matter. The enhanced soil pH following urea fertilization will cause a release of soluble carbon compounds from the humus. This may stimulate microorganism populations and thus decomposition as shown by Salonius (1972). He found the maximum microbial response at moderate urea fertilization (168 kg ha^{-1}) and suggested that the microorganisms lack carbon sources necessary for metabolizing the large amounts of nitrogen at higher dosages of fertilizer.

It is not likely that the effect resulting directly from the fertilizer will persist. Instead, changes in the longer perspective are probably the result of increased litter formation. The time needed for development of high populations of microorganisms and soil fauna depend partly on dosage and type of fertilizer used. In addition, variations between plant species as regards growth rate and litter formation make it difficult to find a general temporal pattern for the response of soil organisms.

In this study the time lag between nitrogen fertilization and increased litter fall may explain the lack of effect at Locksta on the abundance of soil animals. Furthermore, the field layer vegetation at this site was sparse and had probably no significant influence on the total litter formation.

In studies of the total abundance of soil fauna groups, possible changes in relative abundance of different species are overlooked. Such alterations were found by Abrahamsen (1970) and Behan (quoted in Hill *et al.* 1975) and were probably caused either by changes in food resources or by the different species having varying sensitivities to the negative effects of fertilizer. In the present study the springtail *Orchesella bifasciata* could be an example of a species with a higher sensitivity than other species of Collembola. No other indications of changes in relative abundance were detected.

The spatial heterogeneity of soil fauna

populations makes it difficult to detect abundance differences resulting from human influence. A considerable real difference between forms of treatment may be present even when not reflected as a significant difference in a statistical test. The magnitude of the possible "undetected difference" depends on the statistical precision of the study. On the other hand, the natural variation in soil fauna abundance between similar sites is considerable. Although the precision in most estimates in this study is relatively low (cf. standard error estimates in Tables 2—4) it is probably sufficient for detecting differences of greater magnitude than the "natural variation" reflected, for example, in the difference between controls in the present study.

Acknowledgements

The authors were all involved in the planning of the study, in sampling and in preparation of the manuscript. Extraction, counting and identification of enchytraeids were performed by H. Lundkvist and of microarthropods by A. Wirén. Fertilizer experiments established by the Department of Forest Ecology and Forest Soils and the Institute for Forest Improvement were used in this study.

Grants were received from the Swedish Council for Forestry and Agricultural Research and the study was made in cooperation with the Swedish Coniferous Forest Project. We thank several colleagues for their comments on the manuscript.

Sammanfattning

Effekterna av den alltmer omfattande kvävegödslingen av skogsmark är väl kända vad gäller trädtillväxt. Däremot är dess påverkan på marksystemet och speciellt markorganismerna relativt okänd. I litteraturen finns beskrivet både minskade och ökade markfaunapopulationer till följd av kvävegödsling. Graden av påverkan på markfaunan kan tänkas variera beroende på t.ex. dosering, tid efter gödsling och gödseltyp. Den här redovisade studien avsåg att bestämma påverkan på abundansen av enchytraeider och mikroartropoder av 1) skilda doser av ammoniumnitrat, 2) ammoniumnitrat i den dos, som användes vid praktiskt skogsbruk, men vid skilda tider efter gödsling och 3) urea i den dos, som brukas i praktiskt skogsbruk.

Undersökningen ägde rum i tre tallbestånd, Lisselbo (Gästrikland), Locksta (Västerbotten) och Hedemora (Dalarna), med försöksuppläggning i randomiserade block. Antal block, läge och vissa ståndortsdata framgår av Tabell 1. Gödslingsprogrammet för de olika lokalerna redovisas i Fig. 1, som även innehåller provtagningstillfällen och deras relation till gödslingstidpunkter på försöksområdena. Enchytraeid- och mikroartropodprover togs med jordborrar ned till 15 respektive 10—12 cm djup.

Resultat i form av abundansskattningar för enchytraeider och mikroartropoder ges i Tabell 2—4, där även signifikanta skillnader mellan olika behandlingar är indikerade. Totalabundanserna för de skilda grupperna sammanfattas i Fig. 2. Vid Lisselbo uppvisar Enchytraeidae såväl som Collembola och Cryptostigmata signifikanta nedgångar i abundans efter högsta givan ammoniumnitrat. Beträffande de båda andra lokalerna är den enda observerade förändringen en nedgång för en av collembolarterna vid Locksta.

På grundval av denna och andra undersökningar har följande mönster i kvävegödslingens effekter på markfaunan urskilts: 1) En korttidseffekt i form av minskad abundans omedelbart efter gödslingen. 2) En långtidseffekt med gradvis ökande abundans och ett maximum efter ett par år. I vissa fall har bara endera av dessa effekter observerats. En trolig orsak till korttidseffekten är den höjda osmotiska potentialen i markvätskan, vilket ger en s.k. salteffekt. En annan möjlig förklaring är giftigheten hos ammonium i NH_3-form. Verkan av de båda nämnda effekterna är beroende av markfuktigheten vid och efter gödslingstillfället, vilket kan förklara några av skillnaderna i denna studie. Långtidseffekten kan förklaras genom gödslingens påverkan på mikroorganismerna vilka tjänar som föda åt markfaunan.

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