Journal of Environmental Biology
©Triveni Enterprises, Lucknow (India)
Free paper downloaded from: www.jeb.co.in

July 2010, 31, 503-514 (2010)
For personal use only
Commercial distribution of this copy is illegal

Nitrogen mineralization in a high altitude ecosystem in the Mediterranean phytogeographical region of Turkey

Gurcan Guleryuz[1], Salih Gucel*[2] and Munir Ozturk[3]

[1]Uludag University, Science and Arts Faculty, Biology Department, Gorukle, Bursa - 16059, Turkey
[2]Near East University, Environmental Sciences Inst, Nicosia, Northern Cyprus - 33010
[3]Ege University, Science Faculty, Botany Department, Bornova, Izmir - 35100, Turkey

(Received: August 12, 2008; Revised received: February 17, 2009; Accepted: March 02, 2009)

Abstract: *Interrelations exist in the terrestrial ecosystems between the plant type and characteristics of nutrient uptake. Annual net nitrogen mineralization in soils of different plant communities in the high altitude zone of Spil mountain located in the Mediterranean phytogeographical region of Turkey was investigated throughout one year by field incubation method. Seasonal fluctuations resulting from field incubation were markedly higher in autumn and spring than summer. These are mainly associated with the changes in soil moisture being at minimum in the Mediterranean summer. A significant correlation was developed between the net Nitrate (kg NO_3^--N ha $week^{-1}$) production and soil water content ($p<0.05$; $r = 0.316$ in soil of 0-5 cm; $r = 0.312$ in soil of 5-15 cm). The results showed that the annual productivity of nitrogen mineralization shows different values depending on communities. Annual net ammonium (NH_4^+-N) production in the soils of each community was negatively estimated. However, annual net nitrate (NO_3^--N) production (0-15 cm) was higher in grassland (27.8 kg ha y^{-1}) and shrub (25.0 kg ha y^{-1}) than forest (12.4 kg ha y^{-1}) community. While annual net N_{min} values were close to each other in grassland (14.5 kg ha y^{-1}) and shrub (14.1 kg ha y^{-1}), but negative in forest community (-3.6 kg ha y^{-1}). The reasons for these differences are discussed.*

Key words: *Nitrogen Mineralization, Nitrification, High altitude, Grassland, Shrub, Forest*
PDF of full length paper is available online

Introduction

Nitrogen is regarded as one of the important soil constituents influencing biomass production in the ecosystems. The rate of its mineralization in particular is a determining factor in this connection. Latter is generally related to the productivity of the area and forest development and is used as an indicator for the nitrogen uptake (Knoepp *et al.,* 2000; Freppaz *et al.,* 2007; Bradley and Persons, 2007). Several investigators have stressed the ecological significance, dynamics in different type of pastures and the cycling processes of this element in terrestrial ecosystems (Hackl *et al.,* 2000; Schade *et al.,* 2001; Fisk *et al.,* 2002; Nziguheba *et al.,* 2005; Abiven *et al.,* 2005; Valenzuela-Solano *et al.,* 2005; Saraswathy *et al.,* 2007; Guleryuz *et al.,* 2007, 2008; Kizilkaya, 2009; Mukherjee *et al.,* 2009). A lot of experience has been gained during the nitrogen mineralization studies; both gross and net; from different vegetation types of the world in particular those from the temperate zones (Runge, 1983). It is clear now that the nitrogen supply of the sites outside the human management mainly depends on nitrogen mineralization. Under natural conditions amount of inorganic nitrogen taken by the roots is affiliated to the soil type, quality and quantity of organic matter (C, N content, C/N ratio), climate, latitude-longitude, weather and microbial activity (Runge 1983; Hogberg *et al.,* 2007; Seeber *et al.,* 2008). There are three cycles involved in this process "plant-internal", "ecosystem-internal" and "external". The inputs of nitrogen exceed outputs in "productive" ecosystems, whereas in "protective" or "stable" ecosystems inputs and outputs are balanced. The forest soils generally contain insufficient amounts of soil nitrogen limiting forest development and productivity. The biggest nitrogen source of the old forests is generally soil organic matter in particular the ammonium produced by its disintegration (Nadelhoffer *et al.,* 1999a, 1999b; Xiaoyang and Jinfeng, 2007). The biomass produced by the forest trees too is effective in the nitrogen mineralization ratio by affecting soil organic matter accumulation and chemical composition (Lovett *et al.,* 2004; Steinweg *et al.,* 2008). Moreover, the quality and quantity of soil organic matter are regarded as the backbone in the process of mineralization (Chapin, 2003; Pavao-Zuckerman and Coleman, 2005; Matsumoto *et al.,* 2008). However, according to Lovett *et al.* (2004) there are more complex control mechanisms playing their role in this process than the ratio of lignin: N in the litter and concentration of polyphenols or litter or soil characteristics like soil C:N ratio.

Although nitrogen uptake has an impact on the composition of plant cover, plant diversity too controls the nitrogen cycle by effecting the inorganic nitrogen level in the soil (Rehder, 1983; Ozcelik *et al.,* 2008). The interactions between nitrogen uptake and plant cover composition leads to a positive feedback resulting in the creation of resistance against the changes in certain plant groups (Wedin and Tilman 1990). Several studies have been carried out on the Mediterranean-type ecosystems (Schlesinger *et al.,* 1982), but all of them employed indirect methods, *e.g.* litter decomposition calculations or simulations on standard incubations.

* **Corresponding author:** sgucel@hotmail.com

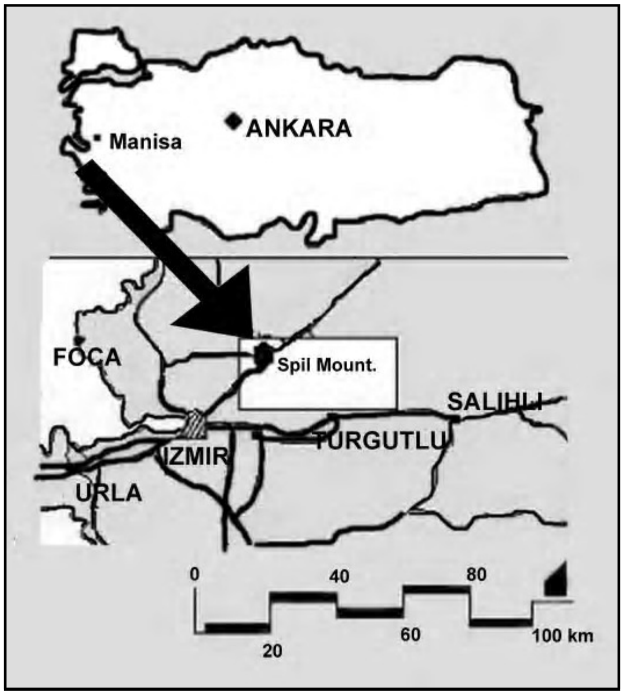

Fig. 1: Map showing the geographical position of the study area from Spil mountain in Manisa-Turkey

Limited information and databases are available on the direct approaches to nitrogen mineralization by the field incubation method for such ecosystems. As such, an attempt has been made and presents here to investigate a high altitude site in the Mediterranean phytogeographical region of Turkey.

Materials and Methods

Study area: Spildag is one of the highest mountains situated in the south of Manisa in the Mediterranean phytogeographical region of Turkey (Fig. 1). Lowest altitude is 60 m and peak is 1513 m, being full of steep slopes. It was delimited as a National Park in 1969; as such a large part of plant cover has been protected, although winter and summer tourism affect the area biotically to some extent. Geologically it belongs to mesozoic and cenozoic period being covered largely by cretase limestones of mesozoic age nd marble. There are two main groups of soils, rendzina and red mediterranean together with naked rocks and pebbles. The area experiences Mediterranean climate with arid summers (June-October) and cold winters and precipitation in the form of snow is very common during the winter with an annual precipitation of 615 mm. The mean monthly soil temperatures range between (10 cm depth) 3-28°C. The means for the coldest and warmest months are 2 and 23°C, respectively.

Sampling procedure: Three types of plant communities namely grassland-(I), shrub-(II) and forest-(III) were used during the course of this investigation. The area of sampling was determined by the least area method as 4 x 6 m and cover and abundance recorded according to the method outlined in detail in Guleryuz and Gokceoglu (1994). The mineral nitrogen in the soils of 3 plant groups in different vegetation types of Spil Mountain were investigated on annual basis. No study is available concerning the nitrogen mineralization in the area. The work was conducted during summer season, during morning hr (10-12 AM), at six-week intervals. For incubation direct field method was employed and at the end samples were buried in the ground. These were taken back at the beginning of following summer. The sampling areas were determined by the least area method as 4 x 6 m. In all 27 samples were collected with 9 samples representing each group. In each of these areas from below the litter layer from two layers of soil 0-5 and 5-15 cm in total 0-15 cm depth samples were taken volumetrically using steel frames 20x20x15 cm and weight determined. The fresh soil samples were passed through 4 mm sieve. A part of these samples was placed in double polyetilen bags and buried at the depth from where it was taken and left back there for incubation till next sampling date according to the method of Runge (1983). Rest of the soil was placed in nylon bags and brought to the laboratory in ice boxes.

Soil physical and chemical analysis: The water content was determined in preset ovens in the laboratory at 105°C for 24 hr. pH and mineral nitrogen (NH_4^+ and NO_3^-) at the measuring time were determined. The dried soil samples were ground and placed in paper bags to determine total nitrogen and organic carbon later. In the samples left for incubation mineral nitrogen was determined and status of mineral nitrogen formation during the year and total annual productivity calculated. While doing this mineral nitrogen values on the date of sampling at the time of measurement were used. During field work minimum-maximum thermometer was placed at 5 cm depth in the soil and temperatures on the sampling dates were recorded, thus annual minimum and maximum soil temperatures noted. The % of total N and organic C in the soils was determined with the help of automatic nitrogen analyzer "Carlo Erba Strumentazione Mod 1400". The % moisture content of the soil samples, plant parts and weights of stones (2 mm <) were taken into consideration and dry weight determined and changed in to kg ha^{-1} value. The mineral nitrogen content of the soil kg ha^{-1} was determined and in order to follow the changes among the sampling date's results were evaluated on weekly basis and for total productivity on annual basis.

The mineral N of soil was determined by Micro-distillation method. NH_4+ and NO_3- were extracted by shaking soil samples (40 g) in Erlenmeyer flasks (500 ml) with 100 ml of a 1% $KAl(SO_4)_2$ solution for 30 minutes. The soil mixture was then filtered through Whatman black-band (No 1) filter paper. A few drops of trichloroethylene were added to inhibit microbial activity and then filtrates were stored at +4°C. Aliquots (20 ml) of the filtered clear solution were treated with 0.2 g of MgO, and steam distilled in a micro-Kjeldahl apparatus; then NO_3^- was reduced to NH_3 by adding 0.2 g of Devarda's Alloy. The distillate was collected in 5 ml of a 2% boric acid, containing 200 µl bromocresol green/methyl red mixed indicator (pH 5.0) and titrated with 0.005 N H_2SO_4. The methods used here are given in detail in Gokceoglu (1988), Guleryuz and Gokceoglu (1994) and Guleryuz *et al.* (2008).

Statistical analysis: The variations in the mineral nitrogen during the year and among the groups were tested with one way variance analysis (One way ANOVA). The variance analysis results were subjected to the Tukey HSD test and attempt made to see if different groups are formed or not. Similar groups were designated with the same letters and different groups with different letters. Also, correlation between net mineral nitrogen production (kg ha week) and some soil factors (pH, %C, %N, C/N ratio, moisture) was tested. All tests were performed at the significance level of 0.05, with the Statistica Ver 6.0 (Stat Soft Inc. 1984-1995) program.

Results and Discussion

Plant diversity: About 600 taxa including 10 being rare taxa, belonging to 329 genera and 81 families are distributed in this national park (Duman 2005). Out of these 60 are endemics embodying 20 rare endemics. Families with highest number of taxa are Asteraceae (79), Fabaceae (72), Lamiaceae (43), Brassicaceae (41), Caryophyllaceae (33). Three types of vegetation dominate the area: these are a) Macchias, b) Mediterranean Forests, c) Mediterranean Forest-Mediterranean Mountain Steppe (Table 1).

Macchia vegetation exists up to 900 m followed by forest vegetation. Most important community in this vegetation is *Quercus coccifera* which includes species like *Phillyrea latifolia, Cistus creticus, Asparagus acutifolius, Jasminum fruticans, Arbutus andrachne, Pistacia terebinthus* ssp. *palaestina, Crataegus monogyna* ssp. *monogyna, Juniperus oxycedrus* ssp. *oxycedrus, Campanula lyrata* ssp. *lyrata, Teucrium chamaedrys* ssp. *chamaedrys.* In addition, we also find local groups of *Quercus infectoria* ssp. *boissieri* and *Spartium junceum*.

Forest vegetation is represented by two communities namely *Pinus brutia* and. *P. nigra* ssp. *pallasiana.* Former is found between 300 to 1000 m., understory being composed of such species as; *Phillyrea latifolia, Quercus coccifera, Asparagus acutifolius, Rubus canescens* var. *canescens* and *Cistus creticus* all macchia elements. Most frequently encountered ground level species are *Origanum sipyleum, Dactylis glomerata* and *Crepis reuteriana* ssp. *reuteriana.* In *Pinus nigra* ssp. *pallasiana* possesses (1000-1400 m) a rich undercover composed of *Luzula forsteri*, *Berberis cretica, Rosa micrantha, Astragalus ptilodes* var. *cariensis, Genista lydia* var. *lydia, Doronicum orientale, Myosotis stricta, Dorycnium graecum, Pilosella hoppeana* ssp. *lydia, Lathyrus laxiflorus* ssp. *laxiflorus, Viola odorata, Ranuncuhis sprunerianus and Cirsium sipyleum.*

Mediterranean forest-Mediterranean Mountain steppe zone embodies communities like *Vicia cracca* ssp. *stenophylla, Paeonia peregrina* and *Juniperus sabina* behween 900-1500 m. Most important species of these communities are *Bromus tomentellus, Festuca ovina, Sanguisorba minor* ssp. *minor, Astragalus angustifolius, Minuartia juniperina, Daphne oleoides* and *Leontodon asperrimus.*

There is a narrow treeless zone at Spildagi which is covered by *Astragalus angustifolius* ssp. *angustifolius* and *Alyssum erolusum.*

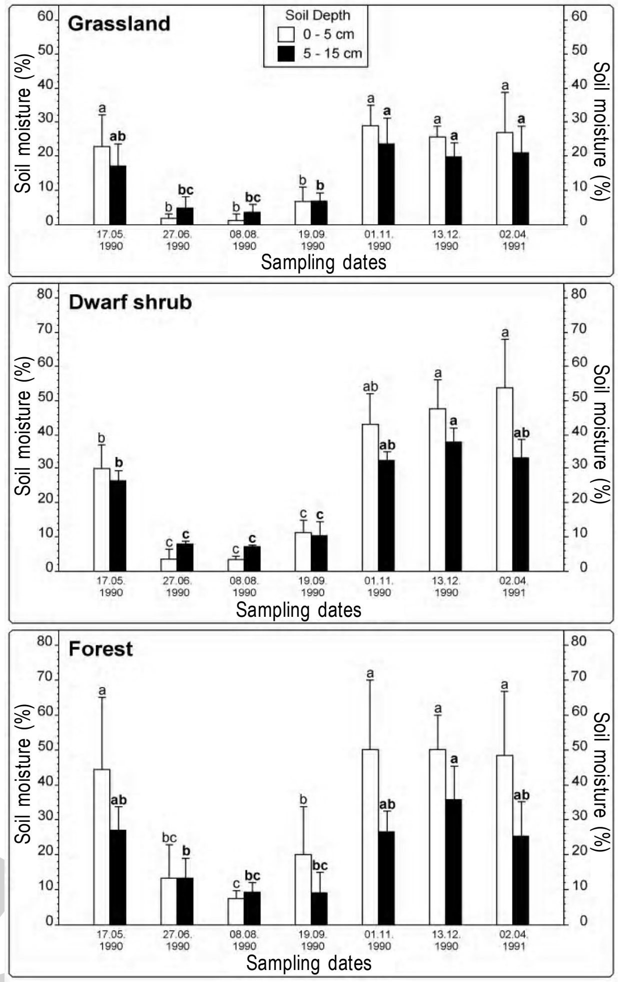

Fig. 2: Soil water content (%) at the two soil layers of the three communities in the course of a year (1990/1991). [Letters on bars represent the difference groups among sampling dates for soil water content (%); mean+SD, n=35]

Two associations of calcicole character are observed on this mountain. These are *Satureja parnassica* ssp. *spylea* and *Omphalodes luciliae* ssp. *scopulorum.* Species commonly found in these communities are *Inula heterolepis, Sedum album, Minuartia anatolica* ssp. *anatolica, Hieracium pannosum, Galium brevifolium, Draba bruniifolia, Alyssum erosulum, Pterocephalus phimosus, Teucriim montanum, Sesleria alba.*

Rocky habitats form a major part of this mountain, abound in such species as *Aurinia saxatilis* ssp. *orientalis, Aubrieta deltoidea, Arenaria sipylea, Dianthus elegans, Sedum lydium, S. acre, Umbilicus rupestris, Rosularia serrata. Aurinia saxatilis* ssp. *orientalis*, *Aubrieta deltoidea*, *Dianthus elegans*, *Sedum lydium*, *S.acre*, *Umbilicus rupestris* and *Rosularia serrata.*

Geophytes dominating Spildagi are *Allium reuterianum, Scilla autumnalis, Ornithogalum nutans, Vesicari neglectum, Tulipa orphonidea, Galanthus gracilis, Colchicum boisseri, Anemone coronaria, A. blanda, Ranunculus reuterianus, Paeonia mascula, P. peregrina, Corydalis solida* ssp. *solida.*

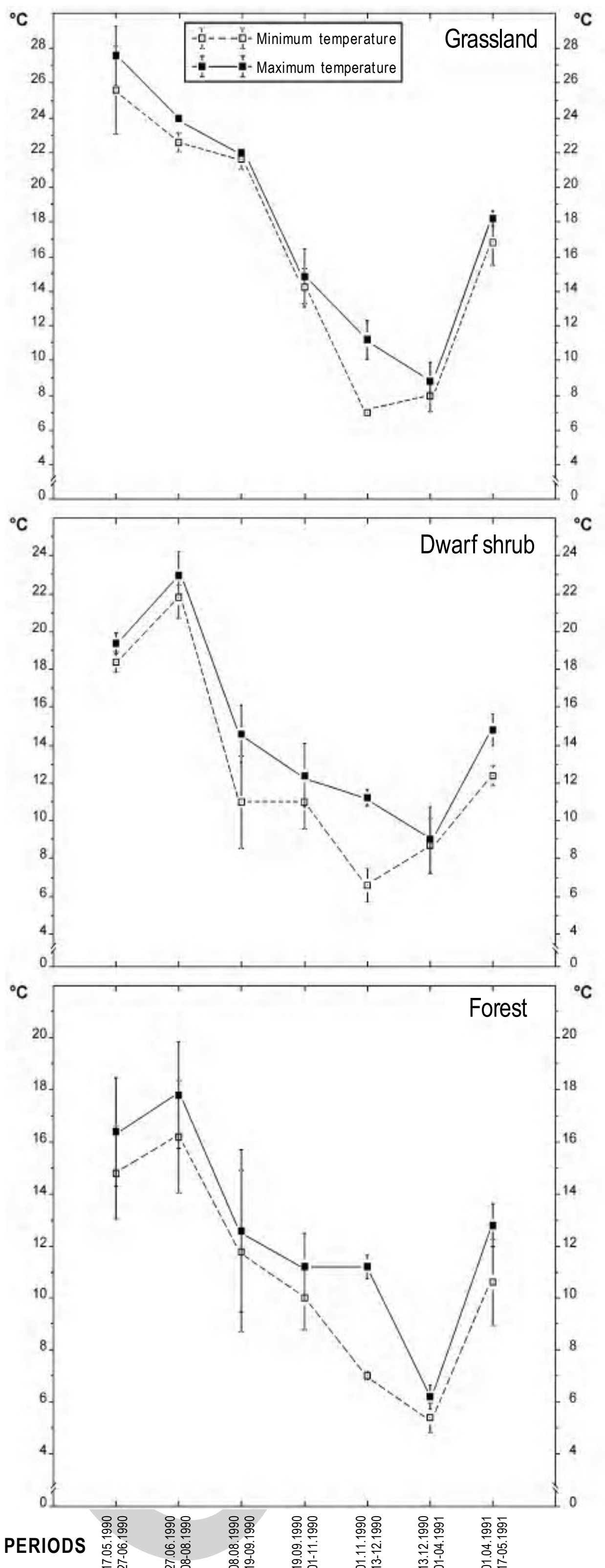

Fig. 3: Soil min/max temperatures (°C) at the two soil layers of the three communities in the course of a year (1990/1991). [Lines represent the standard deviations]

Most important endemics are; *Minuartia anatolica* ssp. *Anatolica, Dianthus erinaceus* var. *erinaceus, Saponaria chlorifolia, Silene sipylea, Colutea melanocalyx* ssp. *davisiana, Astragalus ptilodes* var. *ptilodes, Centaurea sipylea, Verbascuin cheiranthifolium* var. *asperulum, Sideritis sipylea, Stachys tmolea, Origanum sipyleum, Satureja parnassica* ssp. *sipylea, Thymus spyleus, Acantholimon acerosum* var. *brachystachyum, Alkanna areolata* ssp. *sublaevis, Hesperis balansae* ssp. *balansae* and *Tragopogon subacaulis.*

Endemics with restricted distribution due to the isolated situation of this mountain are; *Alkana areolata* ssp. *sublaevis*, *Arenaria sipylea* and *Centaurea sipylea*. These are endemic to this mountain only. The taxa like *Dianthus erinaceus* var. *erinaceus*, *Hesperis balansae* ssp. *balansae* and *Tragopogon subacaulis* are recorded from a few more mountains from Izmir. *Alkanna areolata* var. *sublaevis* is recorded as an endemic under threat at global level, whereas the taxa like *Achillea nobilis* ssp. *sipylea*, *Arenaria sipylea*, *Asperula lilaciflora* ssp. *lilaciflora*, *A. nitida* ssp. *hirtella*, *Astragalus ptilodes* var. *cariensis*, *Bromus sipyleus*, *Centaurea cariensis* ssp. *maculiceps*, *C. sipylea*, *Cirsium sipyleum*, *Comperia comperiana*, *Dianthus erinaceus* var. *erinaceus*, *Echinophora trichophylla*, *Haplophyllum megalanthum*, *Hesperis balansae* ssp. *balansae*, *Ornithogalum alpigenum*, *Silene sipylea*, *Teucrium lamiifolium* ssp. *lamiifolium* and *Tragapogon subacaulis* are recorded as under threat at European level. The taxa under threat at the national level are; *Aethionema polygaloide*, *Allium pictistamineum*, *Anemone blanda*, *A. coronaria*, *Cyclamen hederifolium*, *Galanthus gracilis*, *Orobanche picridis*, *Ranunculus pedatus* ssp. *pedatus*, *Ruscus aculeatus* var. *angustifolius*, *Satureja parnassica* ssp. *sipylea* and *Teucrium flavum* ssp. *hellenicum*. The taxon *Comperia comperiana* is recorded in the addendum of the list prepared for the Bern protocol.

Soil characterization: Main characteristics of the soil are given in Table 2. Soil organic C and N content were determined both on ratio basis (%) as well as kg ha^{-1}. In both layers of soil differences in the communities was significant ($p<0.05$) as regards the C and N content. Forest area was highest and grassland lowest in the difference level as regards the C content. In N content forest in the 0-5 cm and shrubs in the 5-15 cm were in the highest group whereas grasslands were in the lowest group in both the layers. The differences in the soil C/N ratio, water content (%) and pH too were significant ($p<0.05$). C/N ratio was highest in the forest group than others. Soil pH value means although very close to each other in different groups it was lowest in the grasslands and lie in a separate group.

The moisture content in the grassland and shrub communities is higher at the upper horizon (0-5 cm) than in 5-15 cm. The reason for this is that the sampling was done during the morning hours and root density in the upper soil layers of grassland and shrub communities was higher. The difference in the annual means of soil water content was significant among the groups, in both soil layers lowest mean was observed in the grasslands. The changes in the water content within a year

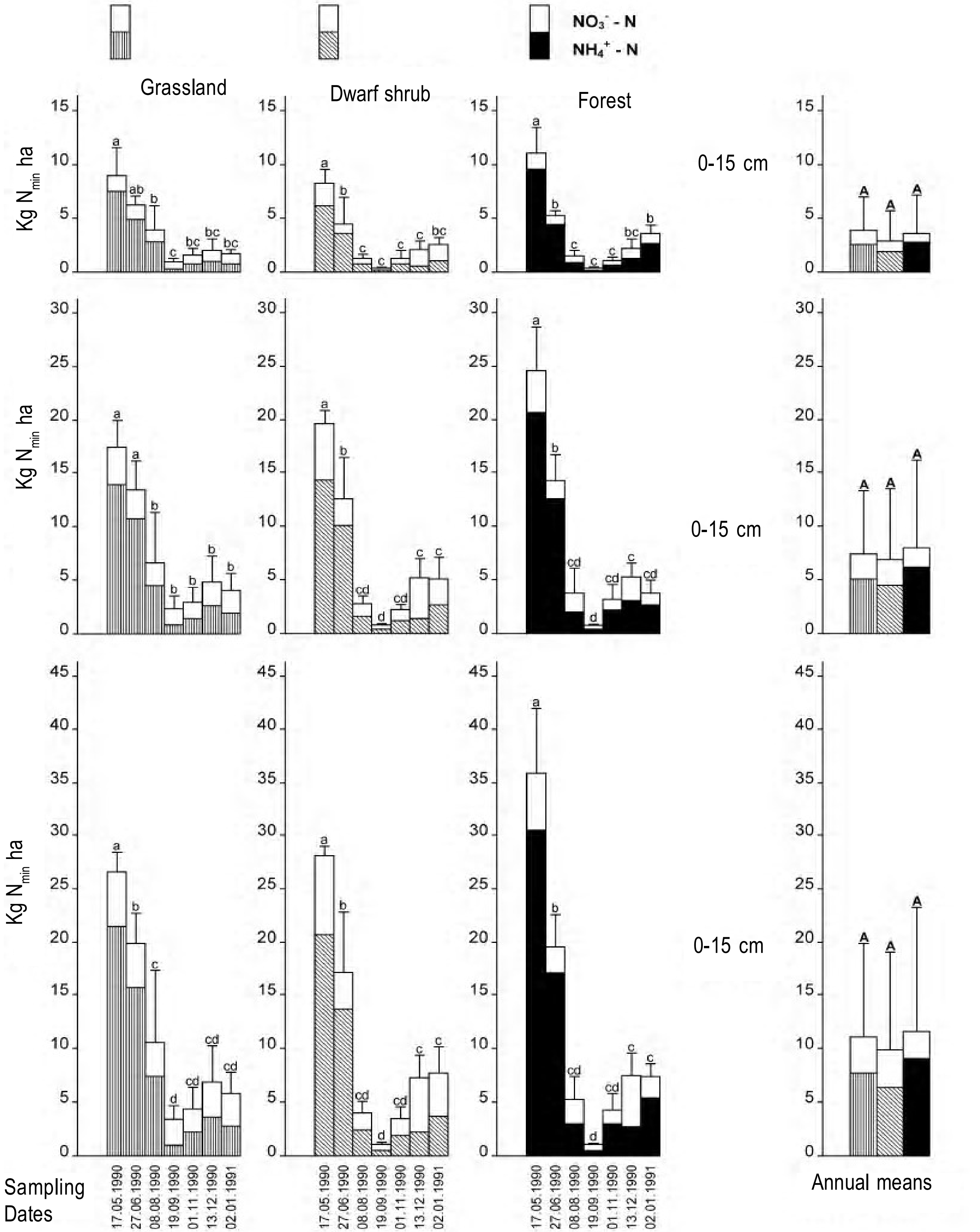

Fig. 4: The seasonal fluctuation in a year of actual mineral nitrogen in three soil layers of three plant communities and their annual means in Spil Mountain, Manisa. [Minor letters on bars represents the difference groups among sampling dates and major letters among communities for annually means and, lines represents the standard deviations for total mineral nitrogen (NH_4^++NO_3^--N); n=35]

Table - 1: Abundance of plant species observed in the sampling sites. Cover abundance figures according to Braun-Blanquet (1964). Only species present in two or more plots are listed. Nomenclature follows Flora of Turkey and the East Aegean Islands (Davis 1965-1985).

Vegetation type	I Grassland						II Shrub					III Forest			
Site size (m)	4x6						4x6					10x10			
Mean high (m)	0.05 (-0.15)						0.10(-0.60)					15			
Cover degree (%)	70	75	90	90	85	55	55	15	20	20	95	95	100	100	100
Species	Sampling sites														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Aegilops umbellata	4	4	3	4	2	.	.	.	.	.	.	.	.	.	.
Vicia cracca ssp. *stenophylla*	1	1	2	1	2	.	.	.	.	.	.	.	.	.	.
Cerastium brachypetalum ssp. *roeseri*	1	1	1	1	1	+	+	+	+	+	.	.	.	.	.
Teucrium chamaedrys ssp. *chamaedrys*	.	1	1	1	1	.	.	.	.	1	.	.	+	+	+
Acantholimon acerosum var. acerosum	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.
Marrubium globosum	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.
Anthemis cretica ssp. *leucanthemoides*	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.
Helianthmum salicifolium	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.
Centaurea cyanus	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.
Astragalus ptilodes var. ptilodes	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.
Bromus sterilis	+	.	.	+	+	.	.	.	+	+	.	.	.	.	.
Hordeum bulbosum	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.
Crupina crupinastrum	.	+	+	+	.	.	.	.	.	.	.	.	.	.	.
Potentilla recta	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.
Trifolium campestre	.	.	+	+	+	.	.	.	.	.	.	.	.	+	.
Arenaria serphyllifolia	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.
Dactylis glomerata	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.
Ononis spinosa ssp. *leiosperma*	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.
Anthemis tinctoria ssp. *tinctoria*	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.
Anthemis pectinata ssp. *pectinata*	.	+	.	+	+	+	+	+	+	+	.	.	.	.	.
Leontodon asperrimus	+	.	+	.	+	+	.	+	.	+	.	.	.	.	.
Alyssum foliosum var. foliosum	+	+	.	.	+	+	+	+	+	.	.	.	.	.	.
Erophila verna ssp. praecox	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.
Lamium amplexicaule	+	+	.	.	.	.	.	.	.	+	.	.	.	.	.
Gagea peduncularis	+	+	.	.	.	+	+	+	+	.	.	.	.	.	.
Centaurea thirkei	.	+	.	.	+	.	.	.	+	+	.	.	.	.	.
Gallium fissurense	.	.	.	+	+	.	.	.	.	+	.	.	.	.	.
Herniara incana	+	.	.	.	.	.	.	+	+	.	.	.	.	.	.
Phleum exaratum	+	.	.	.	.	+	.	+	+	.	.	.	.	.	.
Moenchia mantica ssp. *caerulea*	.	.	+	.	.	.	.	.	.	+	.	.	.	.	+
Vinca herbacea	+	+	.	.	.	.	.	.	1	1	.	.	.	.	.
Sanguisorba minor ssp. *minor*	.	.	.	+	.	.	.	.	.	1	.	.	.	.	+
Poa bulbosa var. vivipara	+	+	1	+	1	+	+	+	+	.	.	+	+	+	1
Juniperus sabina	.	.	.	.	.	3	3	1	1	1	1	1	1	1	.
Juniperus oxycedrus ssp. *oxycedrus*	.	.	.	.	.	1	1	1	1	1	+	+	.	.	+
Acantholimon ulicinum var. ulicinum	.	.	.	.	.	1	1	1	1	1	.	.	.	.	.
Astragalus angustifolius ssp. *angustifolius*	.	.	.	.	+	1	1	1	1	1	+	+	+	.	+
Genista lydia var. lydia	.	.	.	.	.	.	.	.	1	1	1	1	1	.	1
Berberis cretica	.	1	.	.	.	.	.	1	1	1	1	1	1	1	1
Marrubium rotundifolium	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.
Cirsium arvense ssp. *vestitum*	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Rubus canescens var. canescens	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Dianthus erinaceus var. erinaceus	.	.	.	.	.	+	+	+	+	+	.	.	.	.	.
Draba brunifolia ssp. *olympica*	.	.	.	.	.	+	+	+	.	+	.	.	.	.	.
Asperula lilaciflora ssp. *lilaciflora*	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.
Pinus nigra ssp. *pallasiana*	.	.	.	.	.	.	.	.	.		5	5	5	5	5
to be continued Table 1															
Doronicum orientale	.	.	.	.	.	+	.	.	+	+	1	1	1	1	1

Luzula forsteri	.	.	.	.	.	.	.	.	.	.	+	+	+	1	1
Heracleum platytaenium	.	.	.	.	.	.	.	.	.	.	+	1	+	+	+
Ranunculus sprunerianus	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.
Digitalis ferruginea ssp. *ferruginea*	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+
Cirsium sipyleum	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.
Veronica trichadena	.	.	.	.	.	.	.	.	.	.	+	.	.	+	+
Astragalus ptilodes var. cariensis	.	.	.	.	.	.	.	.	.	.	+	.	+	.	+
Viola odorata	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+
Anacamptis pyramidalis	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+
Festuca ovina	+	.	+	+	.	.	.	+	.	+	.	.	1	.	.
Bromus tomentellus	+	+	+	.	+	+	+	+	.	+	+	1	+	+	+
Taraxacum serotinum	+	+	+	.	+	+	+	.	.	+	+	.	+	+	+
Scilla autumnalis	+	+	.	.	.	.	.	.	+	.	+	+	.	+	.
Asyneuma limonifolim ssp. *limonifolim*	.	.	.	.	.	+	+	+	.	+	+	.	.	+	.
Pilosella hoppeana ssp. *lydia*	.	.	.	+	+	.	.	.	.	.	+	.	.	.	+
Galium aparine	.	.	+	+	.	+	+	.	.	.	.	+	.	+	.
Conium maculatum	.	.	.	.	.	.	.	.	+	+	.	.	+	+	.
Muscari neglectum	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.
Thlaspi perfoliatum	.	.	.	.	+	.	.	.	.	.	.	+	+	+	+
Ornithogalum nutans	+	.	+	.	.	+	.	.	.	.	.	.	.	+	.
Crocus pallasii ssp. *pallasii*	+	+	.	.	.	.	+	.	.	.	+	.	.	.	.
Thymus zygoides var. lycaonicus	+	.	.	.	+	+	.	+	.	.	.	.	+	.	.
Thymus sipyleus ssp. *sipyleus*	.	+	.	.	+	+	+	+	.	+	+	+	.	.	+

Table - 2: Soil parameters of three communities (Grassland, Shrub, Forest) at spil mountain in Manisa -Turkey

	Carbon		Nitrogen		C:N	Moisture	pH
Community	**%**	**kg ha^{-1}**	**%**	**kg ha^{-1}**	**(mass ratio)**	**(% Water in dry soil)**	**(H_2O)**
0-5 cm							
Grassland (I)	3.74 ± 1.01^c	16507 ± 5572^c	0.34 ± 0.08^b	1497 ± 480^b	11 ± 2^b	16 ± 13^b	7.8 ± 0.4^b
Shrub (II)	7.75 ± 2.20^b	26847 ± 9622^b	0.61 ± 0.12^a	2107 ± 623^a	13 ± 2^b	28 ± 21^a	8.1 ± 0.4^a
Forest (III)	12.32 ± 5.35^a	36641 ± 18064^a	0.67 ± 0.23^a	1989 ± 835^a	18 ± 4^a	34 ± 22^a	8.0 ± 0.5^{ab}
5-15 cm							
Grassland (I)	2.83 ± 0.64^b	27603 ± 8986^b	0.27 ± 0.07^c	1497 ± 480^b	11 ± 2^b	14 ± 9^b	7.9 ± 0.4^b
Shrub (II)	4.87 ± 1.00^a	38550 ± 8706^a	0.42 ± 0.09^a	2107 ± 623^a	12 ± 1^b	22 ± 13^a	8.2 ± 0.3^a
Forest (III)	5.59 ± 3.47^a	44407 ± 26613^a	0.35 ± 0.13^b	1989 ± 835^a	16 ± 5^a	21 ± 12^a	8.3 ± 0.5^a

±SD

Table - 3: Comparison of the communities regarding the annual net N_{min} productivity estimated in the three soil layers. (n=35)

	Soil depth (cm)	Community		
		Grassland	**Shrub**	**Forest**
NH_4^+-N	0-5	-2.3 ± 2.9^a	-1.1 ± 2.4^a	-5.1 ± 2.3^a
	5-15	-11.0 ± 3.3^a	-9.8 ± 5.4^a	-10.8 ± 7.0^a
	0-15	-13.3 ± 4.7^a	-10.9 ± 6.3^a	-16.0 ± 9.0^a
NO_3^--N	0-5	15.5 ± 4.7^a	11.9 ± 7.6^a	5.7 ± 4.3^a
	5-15	12.3 ± 6.9^a	13.1 ± 6.6^a	6.7 ± 2.8^a
	0-15	27.8 ± 11.0^a	25.0 ± 14.1^a	12.4 ± 6.6^a
NH_4^+ + NO_3^--N	0-5	13.2 ± 6.5^a	10.8 ± 7.4^{ab}	0.6 ± 1.9^b
	5-15	1.3 ± 6.6^a	3.3 ± 4.7^a	-4.2 ± 5.6^a
	0-15	14.5 ± 12.7^a	14.1 ± 10.2^a	-3.6 ± 4.8^b

show that in the three groups and both layers it was significant ($p<0.05$; Table 2). The changes in the soil moisture content depict a typical Mediterranean climatic feature; it is highest in autumn followed by winter and spring periods (Fig. 2). Since there was no station measuring soil temperature in the region min/max thermometer placed in the 0-5 cm layer was used to record the highest and the lowest soil temperature in each period. Annual changes in the mean minimum and maximum temperatures of the areas are given in Fig. 3. The annual changes in the soil minimum and maximum temperatures showed the same model. Minimum soil temperature in the during the year was 7-28°C in the grasslands mean being 16.5 ± 6.9°C, in the shrubs it was 5-23°C and mean was 21.7 ± 5.3°C, in the forest 5-19°C and annual mean 10.8 ± 4.0°C; maximum soil temperature was recorded in the grasslands 8-30°C with a mean value of 18.1 ±

Table - 4: Simple correlation coefficients between net mineral nitrogen (NH_4^+ and NO_3^- kg ha week) and soil factors (n=105, p<0.05 significant, p> 0.05 not significant)

Soil depth	Parameters	r	P	$Y = a + bx$
0-5 cm	NH_4^+ and Moisture	0.144	0.141749	Y = -0.120228 + 0.001891X
	NH_4^+ and C (kg ha^{-1})	-0.100	0.330027	Y = -0.01346 - 0.107414X
	NH_4^+ and N (kg ha^{-1})	-0.034	0.727776	Y = -0.047224 - 0.000013X
	NH_4^+ and C/N ratio	-0.071	0.473382	Y = -0.010336 - 0.004369X
	NH_4^+ and pH	0.261	0.007082	Y = -1.32277 + 0.157859X
	NO_3^- and Moisture	0.316	0.001039	Y = 0.072945 + 0.006252X
	NO_3^- and C (kg ha^{-1})	-0.025	0.800017	Y = 0.252678 - 0.000001X
	NO_3^- and N (kg ha^{-1})	0.112	0.252922	Y = 0.114558 + 0.000064X
	NO_3^- and C/N ratio	-0.176	0.072680	Y = 0.463954 - 0.016428X
	NO_3^- and pH	0.027	0.784653	Y = 0.038959 + 0.024644X
5-15 cm	NH_4^+ and Moisture	0.164	0.094653	Y = -0.421549 + 0.008745X
	NH_4^+ and C (kg ha^{-1})	-0.138	0.158863	Y = -0.077518 - 0.000005X
	NH_4^+ and N (kg ha^{-1})	-0.142	0.146189	Y = 0.028598 - 0.000097X
	NH_4^+ and C/N ratio	-0.041	0.676970	Y = -0.163040 - 0.007285X
	NH_4^+ and pH	0.188	0.055425	Y = -2.58238 + 0.286306X
	NO_3^- and Moisture	0.312	0.001198	Y = 0.009325 + 0.010416X
	NO_3^- and C (kg ha^{-1})	0.036	0.719104	Y = 0.179415 + 0.000001X
	NO_3^- and N (kg ha^{-1})	0.136	0.165026	Y = 0.038252 + 0.000058X
	NO_3^- and C/N ratio	-0.091	0.353357	Y = 0.335727 - 0.010145X
	NO_3^- and pH	0.241	0.013165	Y = -1.66698 + 0.230624X

6.5°C, shrub group 7-24°C and mean value 14.8 ± 4.8°C, forest group 6-21°C and mean 12.6 ± 4.0°C.

Ambient mineral nitrogen content of the soils: Difference among the sampling collection dates was non-significant in all soil layers of the grasslands for actual nitrate (p>0.05), in all other situations it was significant (p<0.05). In all groups NH_4^+-N and NO_3^--N as well as total mineral nitrogen were highest in May, lowest in August (Fig. 4). From the point of view of annual means, difference among the plant communities was not significant (p>0.05) for all cases (Fig. 4). Annual means in the groups were at 0-5 cm 2.61, 1.92 and 2.87 kg ha^{-1}, 5-15 cm 5.13, 4.56 and 6.26 kg ha^{-1}, 0-15 cm 7.75, 6.48 and 9.14 kg ha^{-1} for NH_4^+-N I, II, and III, respectively. The total N_{min} values at 0-5 cm were 3.7, 3.0 and 3.6 kg ha^{-1}, between 5-15 cm 7.4, 6.9 and 8.0 kg ha^{-1} and for 0-15 cm 11.1, 9.9 and 11.6 kg ha^{-1} respectively.

Nitrogen mineralization and annual productivity: In the terrestrial ecosystems, interrelations exists between the plant type and characteristics of nutrient uptake and generally litter rich in nitrogen helps in the nitrogen mineralization more than the one poor in nitrogen (Wedin and Tilman, 1990; Chapin, 2003; Samuel *et al.,* 2005). The nitrogen mineralization in general is higher in the early successional plants as compared to the late successional ones (Wedin and Tilman 1990). In the shrub communities after removal of biomass, litter and humus from the soil an increase in the biomass in the following period has been recorded (Berendse *et al.,* 1989), but annual nitrogen mineralization is low for the first 10 years after the removal of organic cover, it even decreases, as the organic matter content increases in the litter and humus mineralization also increases. While explaining the nitrogen deposition in the grasslands, Wedin and Tilman (1990) have reported that the addition of nitrogen was low, as a result of this replacement C/N ratio decreases, nitrogen mineralization and nitrate increase, high nitrogen losses led to low C deposition. Berendse (1990) has tried to explain the impact of dominating plants on the soils of nutrient poor ecosystems throughout the succession. In the first stages of succession deposition of dead plant remains on the nutrient poor soils is very fast, this deposition of the soil organic matter could result in a 10 times increase in the nitrogen mineralization after few decades, leading to a change from low maximum growth and low biomass loss species to high potential growth and high biomass losing species, litter of low biomass losing species decays with difficulty but litter of the plants with high potential growth rate decay more easily, accordingly throughout the growth of ecosystems, such type of plant compositions determine the increase in the mineralization and change in the species composition has been reported. In the moist meadow communities of high altitudes under same microclimatic conditions soil nitrogen turnover studies have revealed that at the end of growth period net N mineralization and nitrification ratio change with the type of plant cover affecting the structure of plant community and ecosystem functioning. In addition, litter quality (C/N and phenol/N), quantity of litter (aboveground and capillary root production) and diversity in the soil quality have been interrelated.

A seasonal fluctuation in the accumulation of mineral nitrogen under site incubation conditions was observed (Fig. 5). Since each incubation period has different day lengths, net productivity was converted to the weekly values (kg ha $week^{-1}$). According to the weekly net mineral nitrogen productivity, differences in the period

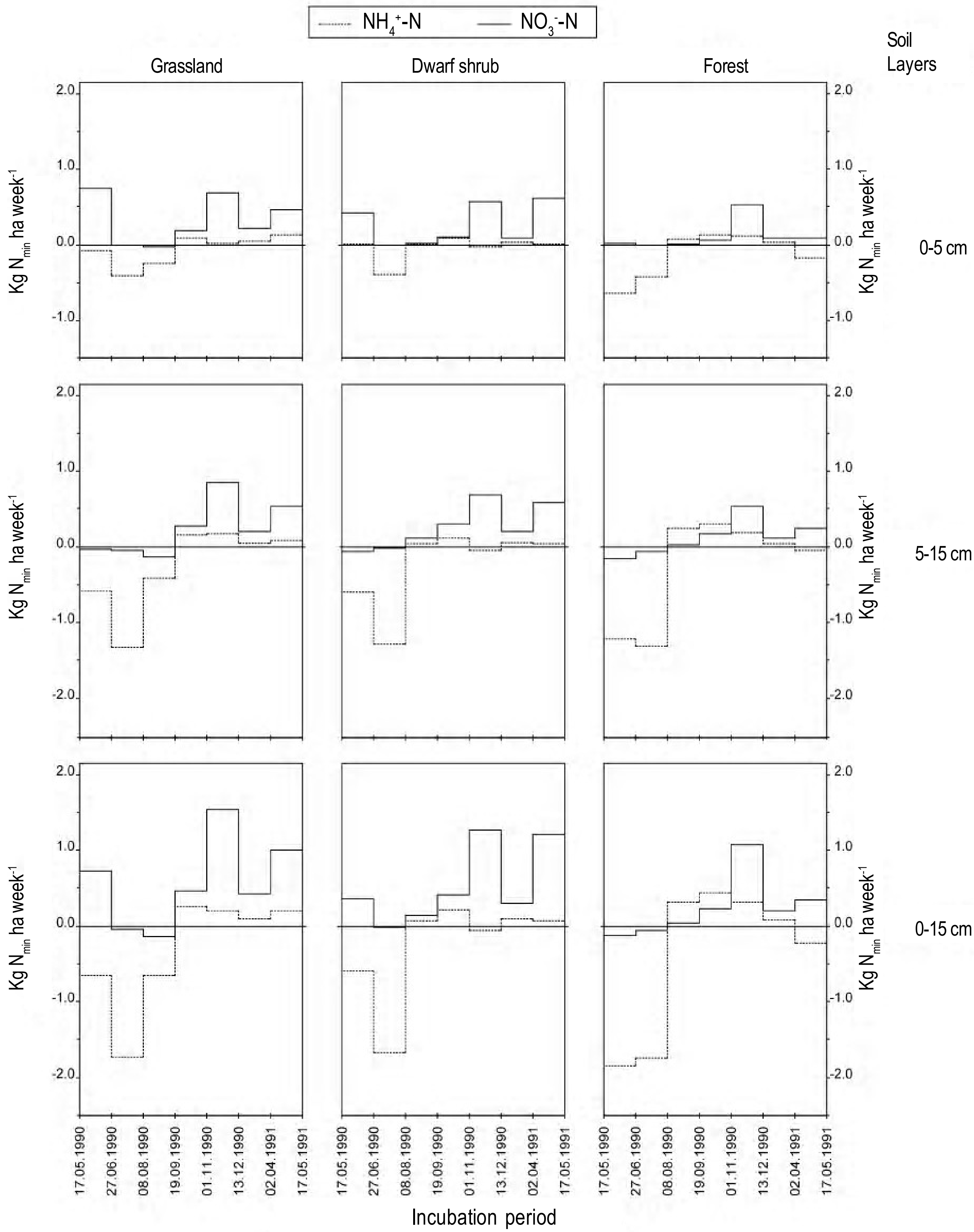

Fig. 5: The seasonal fluctuation in a year of net mineral nitrogen (NH_4^+-N and NO_3^--N) production (kg ha week^{-1}) in different soil layers of three plant communities in Spil Mountain, Manisa. (n=35)

was significant for all cases ($p<0.05$) (Fig. 5), except net NO_3^--N in the 0-5 cm shrub group. The ammonium production at the start was negative from May till September in the grassland and in other two groups during the periods from May to August but increased latter. In the forest group during the last period in particular in the 0-5 cm layer once again a negative productivity was recorded (Fig. 5). Nitrate productivity particularly in the 0-5 cm layer depicted the same model as that resembling soil water content (Fig. 2 and Fig. 5). This model was not seen in 5-15 cm layer. However, as a general model highest mineral nitrogen productivity was in May-June, November-December, and April-May periods which coincided with the precipitation regime of the Mediterranean climate.

Annual net mineral nitrogen productivity differed according to the soil layers and in relation to the mineral nitrogen type (Table 3). The difference among the groups was not significant ($p>0.05$), as regards the NH_4^+-N and NO_3^--N in the 0-5 and 5-15 cm layers, but in the total 0-15 cm layer it was significant ($p<0.05$). Annual net ammonium productivity in the layers of all three groups was negative, but nitrate productivity was positive. In accordance with this annual net NO_3^--N production in the 0-15 cm was calculated as; grassland 27.8 kg ha y^{-1}, shrub 25.0 kg ha y^{-1} and forest 12.4 kg ha y^{-1} (Table 3). Looking at the annual net total mineral nitrogen productivity in the 5-15 cm of the forest, since ammonium productivity was negative at higher amounts total mineral nitrogen productivity was also effected and annual total mineral nitrogen productivity in the 5-15 cm layers was calculated as negative.

The simple correlation and their levels of significance as well as linear regression equations related to the nitrogen mineralization in the study area and main soil factors (C, N, C/N ratio, pH, and soil water content) are given in Table 4. Among the environmental factors soil water content (except 0-5 cm in NH_4^+-N) and pH showed significant correlation ($p<0.05$) with the mineral nitrogen productivity but was not significant for all other levels ($p>0.05$), but an important result here is the correlation between the productivity of NO_3^--N and soil water content (Table 4).

In the upper soil layers (0-5 cm) of the three plant groups studied by us organic C and total N contents are higher and difference among the groups in this zone is highly significant. In the soils of forest group ratio of organic C is higher and accumulation of organic matter too is higher (Table 2), and total N in both layers is close to the shrub layer. Organic C and total N in the soils of grasslands is lower than others (Table 2). This is in coincidence with the fact that organic matter accumulation in the grasslands in general is much lower, moreover grassland communities depict the characteristics of arid land communities. The study area lies in the Mediterranean phytogeographical region with dry hot summers and annual changes in the moisture content of the soils as well as minimum / maximum temperatures are typical of those observed in the Mediterranean climate. The changes in the annual actual and net nitrogen productivity under these climatic conditions are a reflection of the soil moisture content and climatic characteristics (Figs. 2-5). This is fully supported by the soil nitrification values which show a positive correlation (0-5 cm de $r=0.316$; 5-15 cm de $r=0.312$) with soil moisture content which is significant ($p<0.05$) (Table 4).

Similar studies carried out on two other mountains (Karadivit- Kula and Uludag-Bursa) in the Mediterranean part of Turkey (Gokceoglu 1988; Guleryuz and Gokceoglu 1994) have revealed that on the volcanic soils of Karadivit mountain, in the community dominated by *Poa bulbosa-Bromus rigidus* species annual net mineral nitrogen production is 75.0 kg ha y^{-1} and in the *Festuca* cover on the alpine zone of Uludag these values are 25.6 kg ha y^{-1} but 12.9 kg ha y^{-1} in the wet meadows of *Nardus stricta*. In the *Aegilops umbellata* community this value was calculated as 14.5 kg ha y^{-1}, which is higher than *Nardus stricta* cover from the alpine zone of Uludag but lower than others. Similarly a comparison of the *Juniperus sabina J. oxycedrus* cover with other two areas annual total productivity of 14.1 kg ha y^{-1} is lower than *Quercus coccifera* cover (66 kg ha y^{-1}) of Karadivit and *Juniperus communis* (25.1 kg ha y^{-1}) shrub cover of Uludag sub-alpine zone. The forest zone can be compared only with the *Pinus brutia* cover on the volcanic rocks of Karadivit. In the *Pinus nigra* cover studied by us a negative value has been observed because of the higher loss in the ammonium production leading to 12.4 kg ha y^{-1} of nitrate production and for *Pinus brutia* these values have been reported as 28 kg ha y^{-1}. A significant correlation between mineral nitrogen and some soil factors like pH, maximum water holding capacity, total N and organic carbon have been reported by Guleryuz (1998), which support earlier findings except for the *Juniperus* community, amonification being highest in the *Nardus stricta* (Poaceae) dominated grassland community and nitrification in the *Festuca cyllenica* and *F. punctoria* (Poaceae) dominated grassland community.

According to Wedin and Tilman (1990) nitrogen mineralization is higher in the early successional plants as compared to the late successional ones. Berendse et al (1989) found that in the shrub communities (*Calluna vulgaris* and *Erica tetralix* community and *Molinia caerulea* community) after removal of biomass, litter and humus from the soil, there is an increase in the biomass in the new plant cover but annual nitrogen mineralization is low for the first 10 years, after the removal of organic cover it even decreases, as the organic matter content increases in the litter and humus mineralization also increases. *Molinia* effects positively on the mineralization. Wedin and Tilman (1990) have tried to explain the nitrogen deposition in the grasslands of Minnesota after 12 years experimental studies, all the areas dominated by the local mild climate plants show a trend to change in to low diversity mixtures dominated by the cold climate herbs, on the other hand addition of nitrogen is low, as a result of this replacement C/N ratio decreases, nitrogen mineralization and nitrate increases, high nitrogen losses lead to low C deposition, soil nitrate concentrations are related to biomass C/N ratio, if C/N ratio of biomass was above 30 soil nitrate concentrations are low (<1 mg kg^{-1}), if C/N ratio was below 30 net mineral N ratio and nitrate content in the soil increases. Berendse (1990) has tried to explain the impact of dominating plants on the soils of nutrient poor ecosystems throughout the succession. In the first stages of succession deposition of dead plant remains on the nutrient poor soils is very fast, this deposition of the soil organic matter could result in a 10 times increase in the nitrogen mineralization after few decades, this change in the soil structure is important for the plant growth and competition among the species, an increase in the nutrient mineralization during succession could lead to a change from low maximum growth and low biomass loss species to high potential growth and high biomass losing species, litter of low biomass losing species decays with difficulty but litter of the plants with high potential growth rate decay more easily, accordingly throughout the growth of ecosystems, such type of plant compositions determine the increase in the mineralization and change in the species composition has been reported. In the moist meadow communities of alpine tundra under same microclimatic conditions; two dominant species *Acomastylis rossii* and *Deschampsia caespitosa* forming small patches in the community; soil nitrogen turnover studies have revealed that at the end of growth period net N mineralization ratio is 10 times more in *Deschampsia* patches as compared to the *Acomastylis* patches, nitrification ratio is 4 times more. In addition litter quality (C/N and phenol/N), quantity of litter (aboveground and capillary root production), and diversity in the soil quality has been interrelated. As a result, in the alpine tundra plant species have an important control on the soil N turnover, effecting structure of plant community and ecosystem functioning. These results coincide to a great extent with our findings.

We can conclude that seasonal fluctuations resulting from field incubation are marked in grassland and shrub, but less pronounced in the forest. They are mainly associated with the changes in soil moisture being at minimum in the Mediterranean summer. The annual yield of N mineralization is high in grassland and shrub (75 and 66 kg ha y^{-1}), but low in the forest (28 kg ha y^{-1}), where nitrification is inconspicuous. N-mineralization is highly elevated in all sites under favorable conditions of standard incubation (potential mineralization) and the seasonal differences as well as those between the sites are largely diminished.

Acknowledgments

We are obliged to the Volkswagen Stiftung for the partial financial assistance to this project. Our special thanks go to Dr. Qadir Manzoor (Icarda-Aleppo) for critical reading of the manuscript.

References

Abiven, S., S. Recous, V. Reyes and R. Oliver: Mineralisation of C and N from root, stem and leaf residues in soil and role of their biochemical quality. *Biol. Fertil. Soils*, **42**, 119-128 (2005).

Berendse, F.: Organic matter accumulation and nitrogen mineralization during secondary succession in heathland ecosystems. *J. Ecol.*, **78**, 413-427 (1990).

Berendse, F., R. Bobbink and G. Rouwenhorst: A comparative-study on nutrient cycling in wet heathland ecosystems. 2. Litter decomposition and nutrient mineralization. *Oecologia*, **78**, 338-348 (1989).

Bradley, R.L. and W.F.J. Parsons: Net and gross mineral N production rates at three levels of forest canopy retention: evidence that NH_{4+} and NO_{3-} dynamics are uncoupled. *Biol. Fertil Soils*, **43**, 599-602 (2007).

Braun-Blanquet, J.: Pflanzensoziologie-3. Aufl. Springer, Wien New York (1964).

Chapin, F.S.: Effects of plant traits on ecosystem and regional processes: A conceptual framework for predicting the consequences of global change. *Annals of Botany*, **91**, 455-463 (2003).

Davis, P.H.: Flora of Turkey and East Aegean Islands. Vol. 1-9 Edinburgh University Press, Edinburgh (1965-1985).

Duman, H.: Spil Dagi B1 Manisa. *In*: 122 Important Plant Areas in Turkey (*Eds*.: N. Ozhatay, A. Byfield and S. Atay). WWF Turkiye, Istanbul. pp. 149-150 (2005).

Fisk, M.C., D.R. Zak and T.R. Crow: Nitrogen storage and cycling in old-and second-growth northern hardwood forests. *Ecol*., **83**, 73-87 (2002).

Freppaz, M., B.L. Williams, A.C. Edwards, R. Scalenghe and E. Zanini: Labile nitrogen, carbon and phosphorus pools and nitrogen mineralization and immobilization rates at low temperatures in seasonally snow-covered soils. *Biol. Fertil. Soils*, **43**, 519-529 (2007).

Gokceoglu, M.: Nitrogen mineralization in volcanic soil under grassland, shrub and forest vegetation in the Aegean region of Turkey. *Oecologia*, **77**, 242-249 (1988).

Guleryuz, G. and M. Gokceoglu: The nitrogen mineralization and productivity of some plant communities in the Uludag alpine region (Bursa-Turkey). *Turkish J. Bot*., **18**, 65-72 (1994).

Guleryuz, G.: The nitrogen mineralization in soil of some grassland communities in the alpine region of Uludag Mountain, Bursa. *Turkish J. Bot*., **22**, 59-63 (1998).

Guleryuz, G., Serap Kirmizi and Hulya Arslani: Nitrogen Mineralisation in the Soils of Alpine Mat Communities: An Incubation Experiment under Laboratory Conditions. *Turk. J. Bot*., **31**, 277-286 (2007).

Guleryuz, G., E. Titrek and H. Arslan: Nitrogen Mineralization in the Ruderal Sub-Alpine Communities in Mount Uludag, Turkey. *European J. Soil Biol*., **44**, 408-418 (2008).

Hackl, E., S. Zechmeister-Boltenstern and E. Kandeler: Nitrogen dynamics in different types of pasture in the Austrian Alps. *Biol. Fertil. Soils*, **32**, 321-327 (2000).

Hogberg, M.N., Y. Chen and P. Hogberg: Gross nitrogen mineralisation and fungi-to-bacteria ratios are negatively correlated in boreal forests. *Biol. Fertil Soils*, **44**, 363-366 (2007).

Kizilkaya, R.: Nitrogen fixation capacity of Azotobacter spp. strains isolated from soils in different ecosystems and relationship between them and the microbiological properties of soils. *J. Environ. Biol.,* **30**, 73-82 (2009).

Knoepp, J.D., D.C. Coleman, D.A. Crossley and J.S. Clark: Biological indices of soil quality: An ecosystem case study of their use. *Forest Ecology and Management*, **138**, 357-368 (2000).

Lovett, G.M., K.C. Weathers, M.A. Arthur and J.C. Schultz: Nitrogen cycling in a northern hardwood forest: Do species matter? *Biogeochem*., **67**, 289-308 (2004).

Matsumoto, S., N. Ae, Y. Koyama, K. Iijima, R. Kodashima, M. Hirata, J. Kasuga and N. Koga: Evaluation of the mineralizable organic nitrogen in soil using an immunological technique. *Biol. Fertil. Soils*, **45**, 107-111 (2008).

Mukherjee, B., D. Mukherjee and M. Nivedita: Nutrient cycling in a simulated pond ecosystem. *J. Environ. Biol*., **30**, 313-318 (2009).

Nadelhoffer, K.J., M.R. Downs and B. Fry: Sinks for 15-N enriched additions to an oak forest and a red pine plantation. *Ecol. Appl*., **9**, 72-86 (1999a).

Nadelhoffer, K.J., B.A. Emmett, P. Gundersen, O.J. Kjonaas, C.J. Koopmans, P. Schleppi, A. Tietema and R.F. Wright: Nitrogen deposition makes a minor contribution to carbon sequestration in temperate forests. *Nature*, **398**, 145-148 (1999b).

Nziguheba, G., R. Merckx and C.A. Palm: Carbon and nitrogen dynamics in a phosphorus-deficient soil amended with organic residues and fertilizers in western Kenya. *Biol. Fertil. Soils*, **41**, 240-248 (2005).

Ozcelik, R., A.U. Gul, J. Merganic and K. Merganicova: Tree species diversity and its relationship to stand parameters and geomorphology features in the eastern Black sea region forests of Turkey. *J. Environ. Biol.*, **29**, 291-298 (2008).

Pavao-Zuckerman, M.A. and D.C. Coleman: Decomposition of chestnut oak (*Quercus prinus*) leaves and nitrogen mineralization in an urban environment. *Biol. Fertil. Soils*, **41**, 343-349 (2005).

Rehder, H.: Untersuchungen zur Stickstoffversorgung der afroalpinen Vegetation am Mount Kenya. *Verhandlungen Gesellschaft fur Okologie*, **11**, 311-327 (1983).

Runge, M.: Physiology and Ecology of Nitrogen Nutrition. *In:* Encyclopedia of Plant Physiology 12C (*Eds.:* O.L. Lange, P.S. Nobel, C.B. Osmond and H. Ziegler). Springer, Berlin Hiedelberg New York. pp. 164-200 (1983).

Samuel, C.A., J. Shibu, P.K.R. Nair, J.B. Barry, V.D. Nair, D.A. Graetz, D.A. and C.L. Ramsey: Nitrogen mineralization in a pecan (*Carya illinoensis* K. Koch)–cotton (*Gossypium hirsutum* L.) alley cropping system in the southern United States. *Biol. Fertil. Soils*, **41**, 28-37 (2005).

Saraswathy, R., S. Suganya and P. Singaram: Environmental impact of nitrogen fertilization in tea eco-system. *J. Environ. Biol.*, **28**, 779-788 (2007).

Schade, J.D., S.G. Fisher, N.B. Grimm and J.A. Seddon: The influence of a riparian shrub on nitrogen cycling in a sonoran desert stream. *Ecology*, **82**, 3363-3376 (2001).

Schlesinger, W.H., J.T. Gray, D.S. Gill and B.E. Mahall: *Ceanothus magacarpus* chaparral: a synthesis of ecosystem processes during development and annual growth. *Botanical Review*, **48**, 71-117 (1982).

Seeber, J., G.U.H. Seeber, R. Langel, S. Scheu and E. Meyer: The effect of macro-invertebrates and plant litter of different quality on the release of N from litter to plant on alpine pastureland. *Biol. Fertil. Soils*, **44**, 783-790 (2008).

Steinweg, J.M., M.C. Fisk, B. Alexander, P.M. Groffman and J.P. Hardy: Experimental snowpack reduction alters organic matter and net N mineralization potential of soil macroaggregates in a northern hardwood forest. *Biol. Fertil. Soils*, **45**, 1-10 (2008).

Valenzuela-Solano, C., D.M. Crohn and J.A. Downer: Nitrogen mineralization from eucalyptus yardwaste mulch applied to young avocado trees. *Biol. Fertil. Soils*, **41**, 38-45 (2005).

Wedin, D.A. and D. Tilman: Species effects on nitrogen cycling: A test with perennial grasses. *Oecologia*, **84**, 433-441 (1990).

Xiaoyang, C. and S. Jinfeng: Soil NH_{4+}/NO_{3-} nitrogen characteristics in primary forests and the adaptability of some coniferous species. *Front. For. China*, **2**, 1-10 (2007).